JOURNAL OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA

INCORPORATED

VOLUME 45 (1962)

PART 4

PUBLISHED 14TH DECEMBER, 1962

REGISTERED AT THE G.P.O., PERTH FOR TRANSMISSION BY POST AS A PERIODICAL

THE

ROYAL SOCIETY

OF

WESTERN AUSTRALIA

INCORPORATED

Journal
of the
Royal Society of Western Australia

Vol. 45 Part 4

9.—Amosopollis cruciformis gen. et sp. nov., a Pollen Tetrad from the Cretaceous of Western Australia

By Isabel C. Cookson* and B. E. Balme†

Manuscript received—20th March, 1962

Amosopollis cruciformis gen. et sp. nov., an obligate tetrad of monosulcate pollen grains, is described from Lower and early Upper Cretaceous sediments in the Perth Basin, Western Australia. The species is of unknown affinities, but occurs also in Cretaceous sediments from Victoria and appears to have stratigraphical importance.

Introduction

Rich assemblages of spores, pollen grains, hystrichosphaerids and dinoflagellates are known to occur in marine Cretaceous sediments which underlie the Molecap Greensand in the southern part of the Perth Basin, Western Australia. These strata, which are frequently glauconitic, do not outcrop and have, so far, yielded no identifiable megafossils. Their detailed stratigraphy is poorly known but they are at present correlated in a general way with the Osborne Formation, the type section of which occurs between 180 feet and 438 feet in the King Edward Street Bore, Osborne Park (McWhae, Playford, Lindner, Glenister and Balme 1958). Microplankton species from the Osborne Formation and its probable equivalents have been described in two recent papers (Cookson and Eisenack 1958, Cookson and Eisenack 1960), and from the evidence of the dinoflagellate suites, the formation is mainly of Albian-Cenomanian age. No detailed account of the palynology of the Osborne Formation has been published although Cookson (1961) has described *Hoegisporis lenticulifera* Cookson a distinctive plant microfossil which occurs in small numbers in most samples from the unit. Microfloras from the Osborne Formation are characterised by a variety of species of *Gleicheniidites*, and most of the other forms present are trilete spores or saccate pollen grains, which do not differ obviously from species known to occur in early Cretaceous and late Jurassic sediments. Most assemblages, however, contain numerous specimens of an unusual tetrad of monosulcate pollen grains, which has not been recognised in older strata, and which appears to have stratigraphical importance, at least in Western Australia. The purpose of the present note is formally to name and describe this plant microfossil.

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Storage of Material

The holotype and two of the paratypes are stored in the collections of the National Museum of Victoria (N.M.V.) and the third paratype is lodged in the general collection of the Department of Geology, University of Western Australia (U.W.A.). A bulk sample of the type material is also retained in the latter repository.

Systematic Description

Genus **Amosopollis** gen. nov.

Type species.—*Amosopollis cruciformis* sp. nov., Cretaceous, Perth Basin, Western Australia.

Diagnosis.—Pollen grains prolate, in obligate, tight, tetragonal or slightly rhomboidal tetrads. A broad, usually ragged, gaping longitudinal sulcus extends the full length of the distal face. Exine thin, surface finely granulate. Total diameter in lateral view 39-60μ.

Remarks and comparisons.—United tetrads of colpate or porate pollen grains have been illustrated, mainly from Tertiary sediments, in many publications. The majority of forms described have been referred by their authors to living genera (e.g. Traverse 1955) or to broad form categories such as *Pollenites* (e.g. R. Potonié 1934). Pflug and Thomson (in Thomson and Pflug 1953) created the genus *Tetradopollenites* with the brief diagnosis "Pollen zu vieren vereinigt" and cited as the type species *Pollenites ericius* R. Potonié. Subsequently, the name *Tetradopollenites* has been used as a broad category to include *Classopollis* tetrads (Lantz 1958), pollen resembling that of *Typha* (Deák 1960) and tricolpate pollens of uncertain affinities (Traverse 1955). Obviously the original diagnosis of *Tetradopollenites* was insufficiently precise, by modern standards, and it is inadvisable to extend its usage until the definition is amended.

Few of the existing generic names for obligate tetrads have undoubted validity. An exception is *Ricciisporites* Lundblad (= *Tetradosulcites* Erdtman), a species known to occur in the Rhaeto-Liassic of Sweden (Lundblad 1959) and the Liassic of Greenland (Erdtman 1954). A distal sulcus is present in *Ricciisporites* but the type species (*R. tuberculatus* Lundb.) has a thick, heavily clavate exine and is considerably larger than *Amosopollis*.

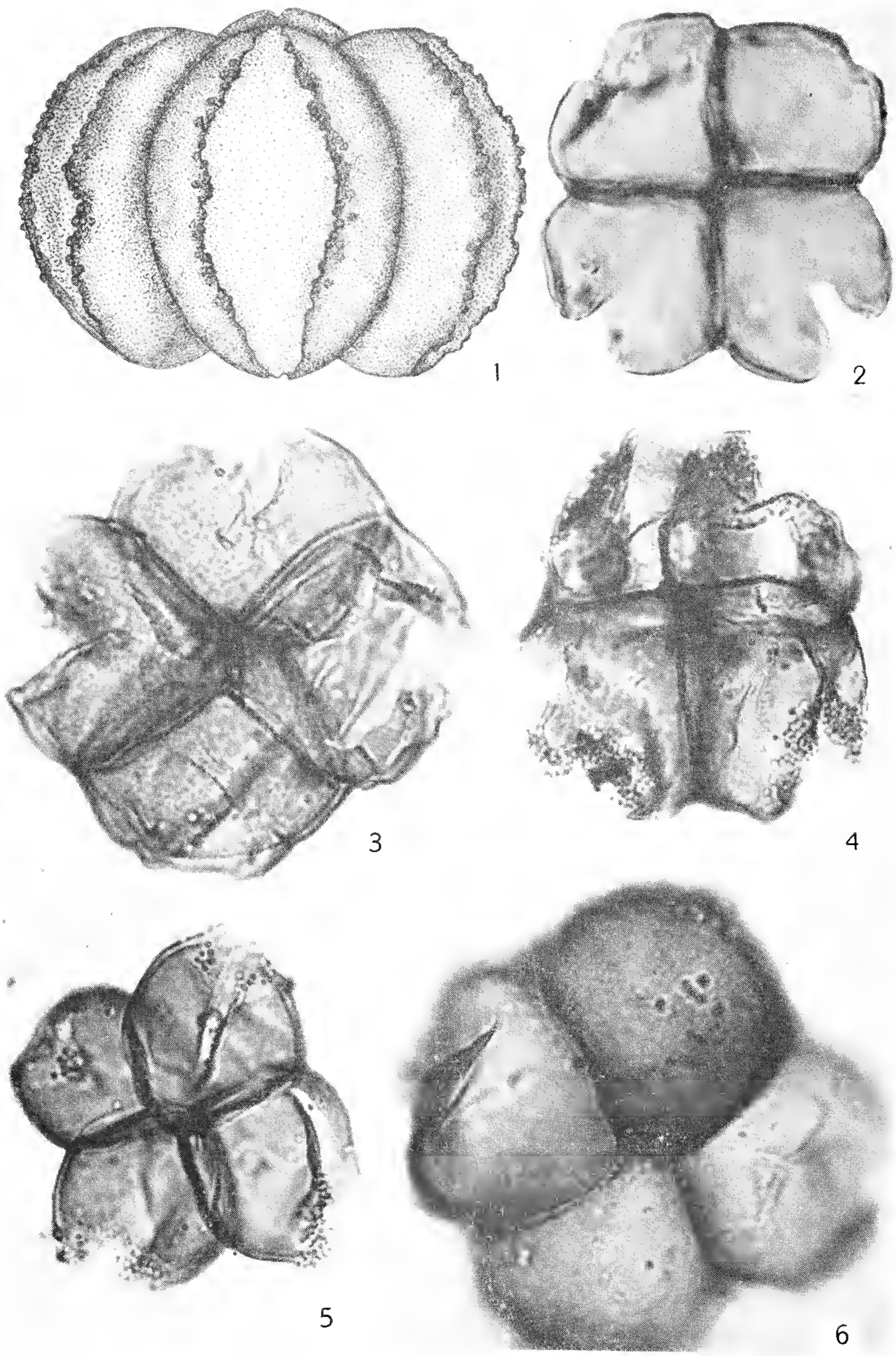

PLATE I

Amosopollis cruciformis Cookson and Balme

Fig. 1.—Reconstruction of mature pollen tetrad in polar view. 1200x.
Fig. 2.—Paratype U.W.A. Slide 47764. Lateral view optical section. 940x.
Fig. 3.—Holotype N.M.V. Slide P21365. Lateral view. 1200x.
Fig. 4.—Paratype N.M.V. Slide P21367. Lateral view showing coarse grana along the margins of the distal sulcus. 940x.
Fig. 5.—Paratype N.M.V. Slide P21366. 940x.
Fig. 6.—Specimen from Fremantle Traffic Bridge No. 2 Bore, 144 ft., showing surface texture in high focus. 1200x.

Amosopollis cruciformis sp. nov.

Plate 1, Figs. 1-6

Holotype: N.M.V. Slide P21365. Paratypes: N.M.V. Slides P21366 and P21367, U.W.A. Slide 47764.

Description.—Holotype preserved in lateral view, consisting of prolate pollen grains united in a slightly rhomboidal tetrad. Exine about 1μ thick, finely granulate, grana less than 1μ in diameter except along the margins of the distal sulcus where grana up to 3μ in diameter may be distinguished. Gaping longitudinal, ragged sulcus extending the full length of the distal face. Total width of holotype 52μ x 52μ, polar diameter of individual grains $26 - 27\mu$.

In paratypes P21366 and P21367 the development of coarser grana along the margins of the distal sulcus can be clearly seen. These localized coarse grana are characteristic of *Amosopollis cruciformis,* although it is uncertain whether they represent true sculptural elements or general breakdown of the exine during dehiscence.

Dimensions.—Total diameter in lateral view $39 - 60\mu$; length of individual grains $26 - 43\mu$ (20 measured specimens).

Locus typicus.—West Australian Petroleum Pty., Ltd., seismic shot hole B1, 4 miles north of Gingin, Western Australia. Dark green, glauconitic, sandy shale from 190 - 220 ft. (Sample U.W.A. 43985). ? Albian-Cenomanian (Cookson and Eisenack 1960).

Known stratigraphic range in Western Australia.—Albian (perhaps late Aptian)—Cenomanian.

Remarks.—*Amosopollis cruciformis* is easily recognised even in poor states of preservation, and has been found in almost all samples from the Osborne Formation and its presumed correlatives. It is seldom common, but its form is sufficiently distinctive to enable its easy recognition in low concentrations. It would be unwise to speculate as to the affinities of *Amosopollis cruciformis.* Morphographically it resembles in some ways the pollen of certain living monocotyledons, but an angiospermous origin seems unlikely from the evidence of its associated microfossils. None of the other microfloral elements in assemblages from the Osborne Formation suggests an angiosperm component in the Albian-Cenomanian floras of south-west Western Australia.

Distribution

Perth Basin

Perth Area.—The species has been recorded from sediments of ? Albian-Cenomanian age (upper part of the Osborne Formation) in King Edward Street Bore, Osborne Park, 265-295 ft.; Roberts Rd. Bore, Osborne Park, 470-490 ft.; Subiaco Bore, 358 ft., 436 ft.; Powerhouse Bore, East Perth, 478 ft. It has also been recorded in sediments of Albian or uppermost Aptian age (lower part of the Osborne Formation) in the Powerhouse Bore, East Perth, 590 ft., 640 ft.

Fremantle District.—It has been recorded from the ? Albian-Cenomanian rocks in Attadale Bore, 104 ft., 164 ft., 354 ft., 428 ft., 479 ft.; Fremantle Traffic Bridge No. 2 Bore, 114 ft., 144 ft., 168 ft., 173 ft.; Fremantle Traffic Bridge No. 5 Bore, 100 ft.; Hampden Rd. Bore, 398-430 ft.; and from rocks of Albian or uppermost Aptian age in Attadale Bore, 529 ft., 539 ft.; Fremantle Traffic Bridge No. 2 Bore, 220-230 ft.; Jandakot Bore, 450 ft.

Otway Basin, Victoria

The species has been recorded from Frome-Broken Hill Co.'s Port Campbell No. 1 Bore, 5,705-5,708 ft., 5,931-5,934 ft.; Port Campbell No. 2 Bore, 7,403-7,408 ft., 7,904-7,913 ft., 7,913-7,930 ft., 8,174-8,182 ft.; Port Campbell No. 3 Bore, 4,676-4,693 ft., 4,781-4,792 ft.; Flaxmans Hill No. 1 Bore, 6,375-6,391 ft., 6,663 ft., 7,200 ft.

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10.—Description of Panulirus cygnus sp. nov., the Commercial Crayfish (or Spiny Lobster) of Western Australia

By R. W. George*

Manuscript received—19th June, 1962

The Western Australian commercial crayfish has been compared with topotypical material of *Panulirus longipes* (from Zanzibar) and *P. japonicus* (from Japan) from both of which it is distinctive. It is therefore described as a new species—*Panulirus cygnus*. Notes on the biology and life history (including descriptions of the puerulus and some phyllosoma stages) are given.

Introduction

In 1934, Mr. L. Glauert, former Director of the Western Australian Museum, doubting the identification of *Panulirus penicillatus* given by Dakin (1919) for the Western Australian crayfish, sent a specimen of it to Dr. Isabella Gordon at the British Museum. After using an unpublished key of Dr. W. T. Calman, Dr. Gordon replied: "It appears to belong to *P. longipes* M. Edw." (in litt. 27.ix.1934). As a result of that identification, the name *Panulirus longipes* (Milne Edwards) 1868 has been applied to this species in fishery reports (Sheard 1949, 1954; Taylor 1956; George 1957, 1958) and for the purpose of Fisheries Regulations since that time. Some doubt about this identification was expressed by Sheard (1949, p. 10) but since he had no specimens from other localities with which to make satisfactory comparisons, he thought it "better to retain the name *Panulirus longipes* for the Western Australian commercial species". The Western Australian population is different from *P. longipes* and from all other species of spiny lobster.

Recent work by Dr. L. B. Holthuis and myself has indicated that a full revision of the *P. japonicus* - *P. longipes* complex of Palinuridae is needed. Such a revision will soon be presented jointly by us. In view of the requirements of fisheries workers for a name for the Western Australian form for use in its rapidly increasing literature it has been decided that this description be published immediately.

Genus **Panulirus** White

Marine crayfish with long flagellae on the antennules; dorsally smooth supraorbital horns, endopod of pleopod of second abdominal segment of female without stylamblys, antennal base with stridulating organ, carapace cylindrical (after Holthuis 1946).

Panulirus cygnus† sp.nov.

Panulirus penicillatus; Dakin 1919.
Panulirus longipes; Anon. 1936; Glauert 1936; Beck and Sheard 1949; Sheard 1949, 1950, 1954; Sheard and Dicks 1949; Kubo 1954 (part); George 1957, 1958; Hodgkin, Marsh and Smith 1959; Ride and Serventy 1961.

Diagnosis

A species of *Panulirus* with uninterrupted abdominal grooves each continuous with corresponding pleural groove, with unmarked reddish carapace, spotted abdomen and without endopod on pleopod of second abdominal segment of male.

Material Examined

Holotype. (Plate I) Adult male 104 mm carapace length‡, measured in the mid-line from the anterior transverse ridge between the supraorbital horns to the posterior margin of the carapace. Total length 290 mm (to end of telson) W.A.M. 90-62. Collector R. W. George 13.xi.1961.

Paratypes. 41 males (13 to 119.7 mm c.l.), 53 females (9 to 120 mm c.l.), 2 specimens sex indeterminate (8.3 and 8.4 c.l.) from between latitudes 21°45′S. and 32°16′S. at North West Cape (21°45′S. 114°10′E.), Point Cloates, Dirk Hartogs I., Abrolhos I., Geraldton, Dongara, Beagle I., Cervantes I., Green I., Lancelin I., Yanchep, Quinns Rocks, Rottnest I., Fremantle, Garden I., Point Peron (32°16′S. 115°41′E.). W.A.M. 9319, 257/60-37, 64/5-53, 40/1-58, 51-58, 53/4-58, 69-58, 91/125-62; R.M.N.H. (Leiden) D 13107.

Type locality. Radar Reef, Rottnest Island, Western Australia (32°00′S. 115°30′E.), in reef pool at depth of 1 metre.

Description of Adult

Holotype.—In addition to features characteristic of *Panulirus* described above, flagellum of exopod of third maxilliped multiarticulate (Fig. 1a) and reaches to level of middle of merus. Single uninterrupted transverse groove to tergum of each abdominal segment (Plate I) (on the basis of these two features, *P. cygnus* keys out to either *P. japonicus,* e.g. Barnard 1950, p. 547 or to *P. longipes,* e.g. Sheard 1949, p. 41 and Kubo 1954, p. 96). Antennular plate with 7 spines arranged in two posteriorly diverging rows (4 in the right row, 3 in the left row) behind the principal pair (Fig. 1d). Transverse grooves of second to fifth abdominal segments joined to and continuous with corresponding pleural groove (Plate II, Fig. 2); grooves covered by fringe of setae. Posterior half of each abdominal tergum with transverse band of short erect setae, decreasing in abundance on posterior segments. Pleopod of second abdominal segment without endopod (Fig. 1b). Mid posterior margin of thoracic sternum with pair of small teeth (Fig. 1e). Triangular plate (referred to as Plate D) at antero-lateral margin of first abdominal

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† This name was selected since the Swan is Western Australia's emblem.

‡ This measurement is hereafter characterised by the abbreviation c.l. immediately after the measurement.

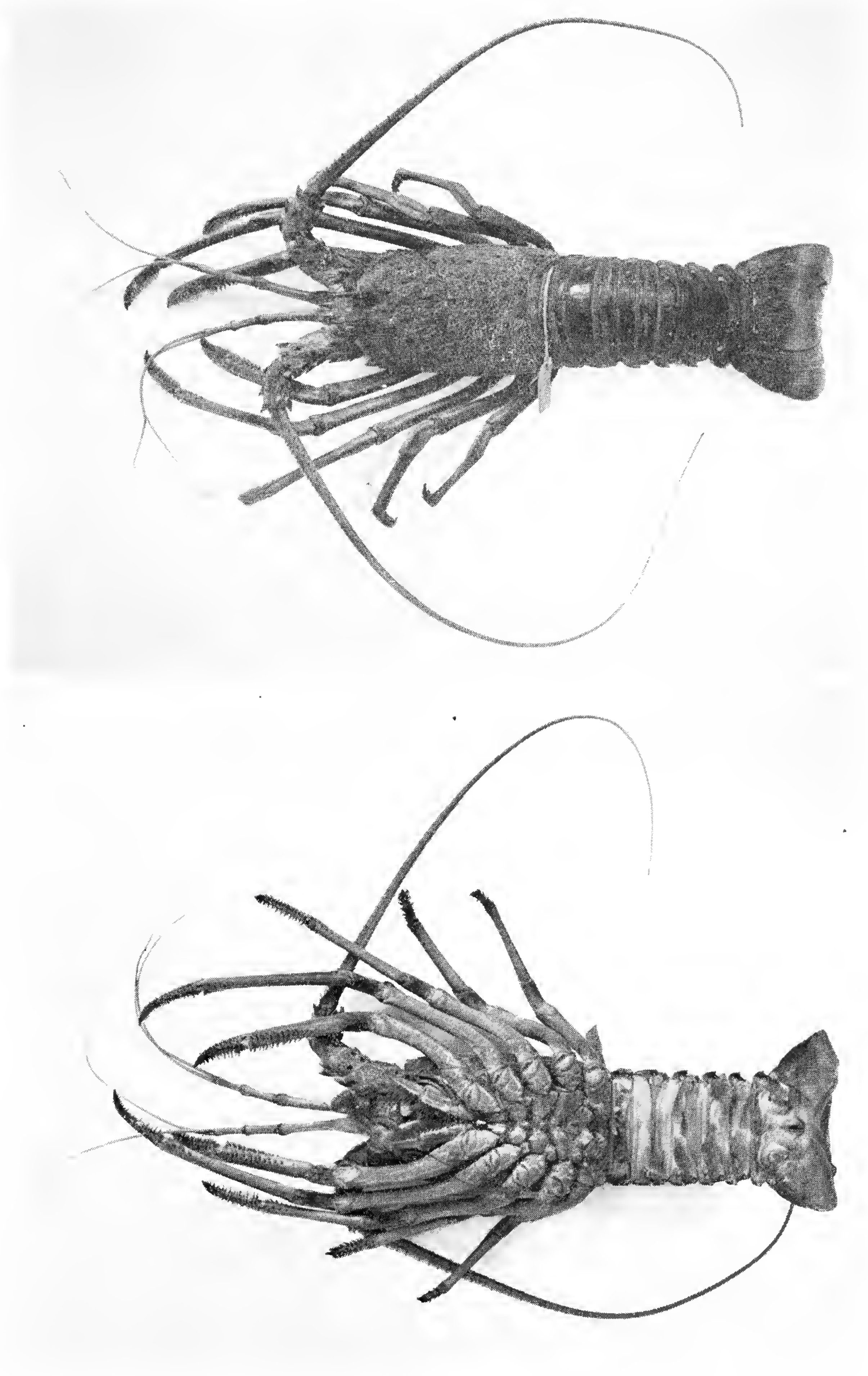

PLATE I

Male Holotype of *Panulirus cygnus* sp.nov., Radar Reef, Rottnest I., Western Australia, in reef pool, 1 metre, R. W. George, 13.xi.1961 W.A.M. 90-62 *c.* ¼ x nat. size.

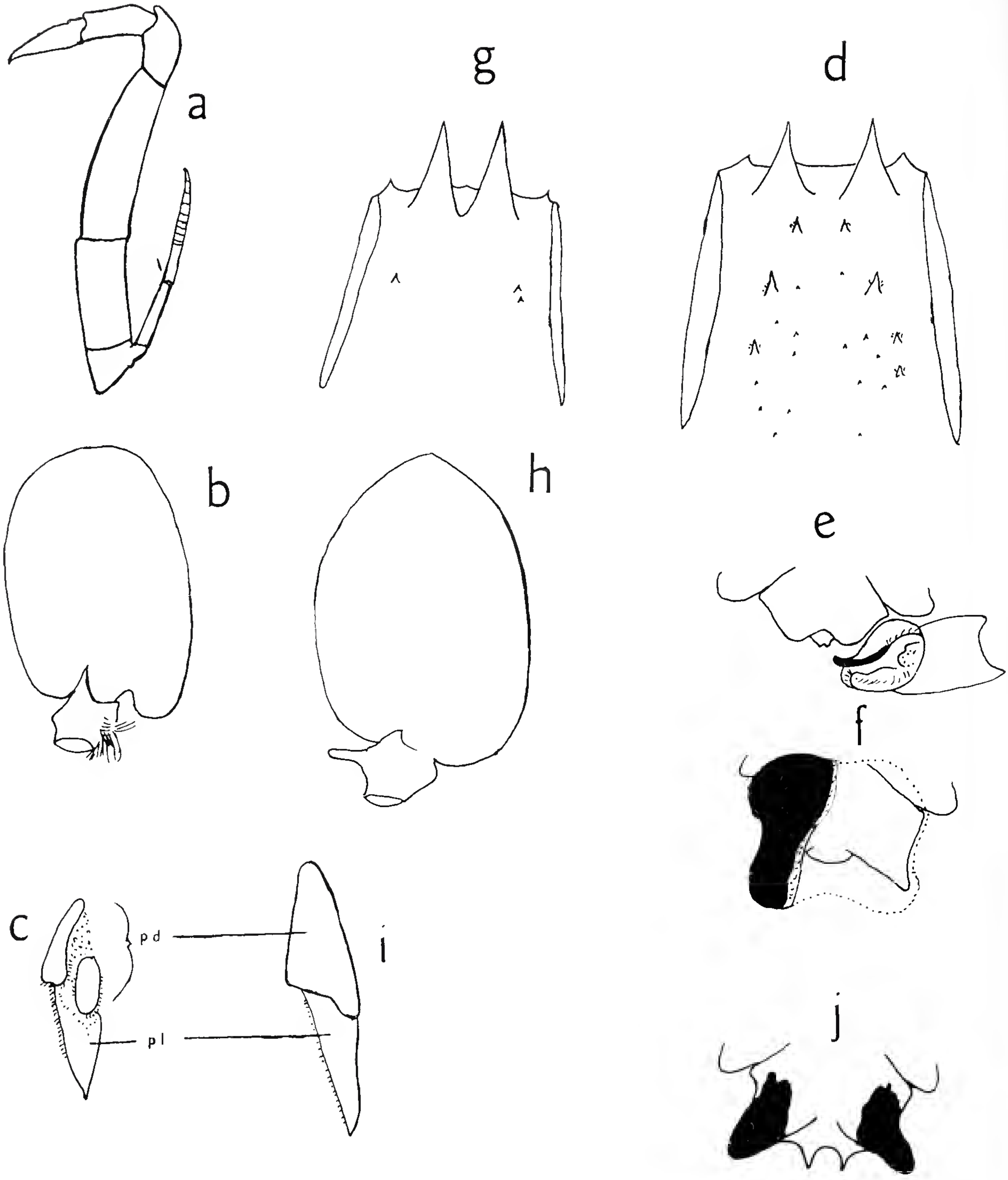

Fig. 1.—(a-e) *Panulirus cygnus* sp.nov. holotype male. (a) left third maxilliped, setae omitted, from below, *c.* nat. size. (b) left pleopod of second segment of abdomen, from behind, *c.* 1⅓ x nat. size. (c) pleuron (pl) and "plate D" (pd) of first abdominal segment, from left. Note the vertical division of "plate D" by a hairy groove, *c.* nat. size. (d) antennular plate, from above, *c.* 1½ x nat. size. (e) posterior thoracic segment, from below, *c.* ¾ x nat. size. (f) *Panulirus cygnus* sp.nov. posterior thoracic segment of mated female W.A.M. 91-62, part of spermatophore removed, from below, *c.* nat. size. (g-h) *Panulirus japonicus* (von Siebold) male c.l. 69.8 mm W.A.M. 126-62. (g) antennular plate, from above, *c.* 2 x nat. size. (h) left pleopod of second segment of abdomen, from behind, *c.* 2½ x nat. size. (i-j) *Panulirus longipes* (Milne Edwards) mated female W.A.M. 130-62. (i) pleuron and "plate D" of first abdominal segment, from left. Note that "plate D" is not divided, *c.* 1¼ x nat. size. (j) posterior thoracic segment, from below, *c.* ¾ x nat. size.

segment divided vertically by groove containing erect setae (Fig. 1c). Carapace dark red without obvious spots or markings, abdomen spotted dorsally and laterally; each walking leg with broad pale longitudinal stripe on dorsal surface and less obvious, narrower, ventral and lateral stripes.

Variation in Paratypical Series.—In the series of 97 specimens examined, variations in the colour intensity, number of spines on the antennular plate, the two thoracic teeth, the division of Plate D, and the distribution of setae on the abdominal terga were found; these variations are associated with growth, sex or geographic distribution.

(a) Colour. The background colour varies in intensity from pink to dark red. Dark red is the usual colour for fresh specimens of all sizes, but in November and December, pale pink crayfish accumulate in the shallower waters (George 1959). These "white" crayfish do not vary from the "red" in the colour *pattern* of uniform non-spotted carapace, spotted abdomen, and broad striped legs. In alcohol, specimens may fade to yellow.

(b) Antennular Plate Spines. The total number of spines in the two main rows behind the principal spines may be 4, 5, 6, 7 or 8 in specimens larger than 30 mm c.l. All specimens smaller than 30 mm c.l. have 6 spines (3 pairs), some of which may show as sharp prominences in the position of the incipient spine. Smaller spines or tufts of erect setae may be found covering the remainder of the plate.

(c) Thoracic Teeth. In the paratypical series, the presence or absence of thoracic teeth is apparently correlated with sex and size. The puerulus stage (see p. 108) has no teeth and teeth develop subsequently so that at 20 mm c.l. all animals possess them. Males subsequently retain the thoracic teeth but females carrying a spermatophore or fibrillar pleopods do not have them (Fig. 1f). There are no specimens of mature females in the series which were collected during the non-breeding season.

(d) Plate D. Specimens in the series from localities between Point Peron, near Fremantle, and Dirk Hartogs I. and greater than 60 mm c.l. all have Plate D divided by a hairy groove as described and figured for the holotype; the depth and extent of this groove in Plate D varies in specimens smaller than 60 mm c.l., some show the hairy groove clearly, others have a very narrow, very shallow groove with sparse setae in it and others have no groove and no setae at all. None of those smaller than 20 mm c.l. have a distinct groove.

Specimens greater than 60 mm c.l. from areas north of Dirk Hartogs I. (i.e. from Point Cloates and North West Cape) do not always have the distinct hairy groove on Plate D but show the full range of variation described above for smaller sizes from the more southern areas.

(e) Setae on Abdominal Terga. The variation in this character, like that in Plate D, is best considered by separately examining the northern and southern specimens. All specimens in the series from localities between Point Peron and Dirk Hartogs I. and of greater than 70 mm c.l. have bands of setae on the posterior region of all abdominal segments although the setae on segments 5 and 6 may be sparse. Those specimens in the size range 30 to 70 mm c.l. have the bands of setae on segments 1, 2 and 3 and may or may not have them on segments 4, 5 and 6 while specimens smaller than 30 mm c.l. only occasionally have sparse setae on segments 2 and 3 but none on segments 4, 5 and 6.

The last two abdominal segments of the specimens from Point Cloates and North West Cape are without bands of setae and some of these specimens lack the setae on segments 4, 3 or even 2. In these specimens, setae on other parts of the crayfish are either sparser or absent compared with those on crayfish from the southern areas; the parts examined which bear setae are: the first joints of the antennal and antennular peduncles, the epistome and the thoracic sternum.

Comparison with Similar Species

P. cygnus sp. nov. is compared below with the most similar species of *Panulirus*, *P. japonicus* (von Siebold) 1824 and *P. longipes* (Milne Edwards) 1868.

Material

For the comparison with the series of *P. cygnus*, the following specimens were examined from the Western Australian Museum (W.A.M.), Queensland Museum (Q.M.) and the Australian Museum (A.M.).

P. longipes.—Topotypical Material, Zanzibar, 1 male (75 mm c.l.), 1 female (87 mm c.l.) A. J. Bruce, 21.v.1960 W.A.M. 130-62. Australian Material.* Heron I., Queensland, 2 females (92 and 100 mm c.l.) R. W. George, 25.v.1961 in reef pool, W.A.M. 129-62 and 1 male (68 mm c.l.) carapace only, R. Manning, May 1961, W.A.M. 127-62. Off Ballina, N.S.W., 1 female (110 mm c.l.) carapace only, A. Heynatz, June 1959, 120 metres W.A.M. 131-62. Evans Head, N.S.W., 1 male (110 mm c.l.) R. Paddon, 29.i.1935 Q.M. W596, and 1 female (123 mm c.l.) State Fisheries Department, December 1926 A.M. P8747 and 1 female (109 mm c.l.) State Fisheries Department, December 1931 A.M. 10169. Stockton Bight, N.S.W., 1 male (62 mm c.l.) A. A. Racek, May 1955 A.M. 13025. Japanese Material, Wakayama, Japan, E. Harada, March 1960 W.A.M. 128-62.

P. japonicus.—Topotypical Material. Japan, 3 males (65.7 to 69.8 mm c.l.) 3 females (48.9 to 63.0 mm c.l.) I. Kubo, 4.x.1960 W.A.M. 126-62.

Comparison

Adult specimens of *P. cygnus* are readily separated from *P. japonicus* by the following characters:

(a) The antennular plate of *P. cygnus* has 4-8 spines arranged in two rows behind the principal pair of spines (Fig. 1d.) whereas *P. japonicus* has no spines or a few very small scattered spinules in this position, (Fig. 1g).

* This and the Japanese material here assigned to *P. longipes*, differs from the topotypical material in the colour of the legs and details of the morphology of Plate D. This variation within *P. longipes* will be fully discussed by Holthuis and George in a forthcoming revision.

1

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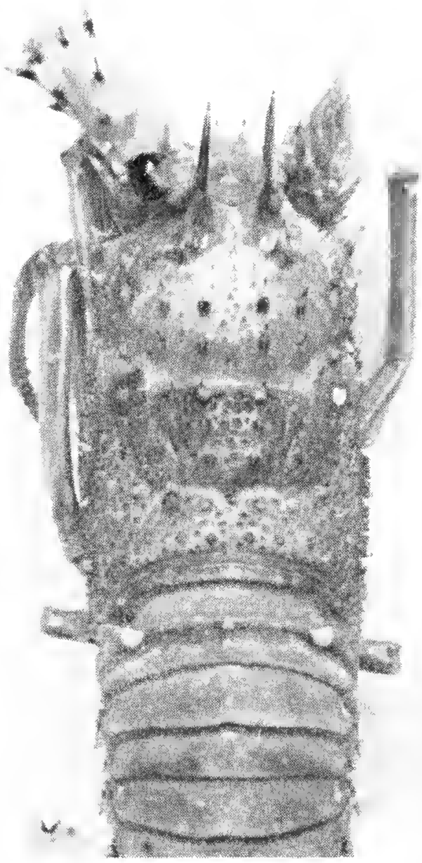

3

4

PLATE II

Fig. 1.—*Panulirus japonicus* (von Siebold), W.A.M. 126-62 c.l. 69.8, from left. *c.* $\frac{3}{4}$ x nat. size. Fig. 2.—*Panulirus cygnus* sp.nov. holotype, from left. *c.* $\frac{1}{3}$ x nat. size. Fig. 3.—*Panulirus longipes* (Milne Edwards) Japan, W.A.M. 128-62 c.l. 64.2 mm, dorsal view. *c.* $\frac{2}{3}$ x nat. size. Fig. 4.—*Panulirus longipes* (Milne Edwards) Zanzibar, W.A.M. 130-62 c.l. 75 mm, dorsal view, *c.* $\frac{1}{2}$ x nat. size.

(b) The transverse grooves of the second to fifth abdominal segments of *P. cygnus* are continuous with the corresponding pleural grooves whereas in *P. japonicus* the transverse grooves of segments 2, 3 and 4 at their lateral ends curve forward and end abruptly before reaching the pleural grooves (Plate II, Fig. 1).

(c) The male pleopod of the second abdominal segment of *P. cygnus* does not have an endopod whereas in *P. japonicus* there is a distinct endopod on that pleopod (Figs. 1b, 1h). This endopod of *P. japonicus* figured here (Fig. 1h) is not as foliate as that of the specimen of *P. japonicus* figured by Holthuis (1946).

Adult specimens of *P. cygnus* and *P. longipes* are very similar morphologically but can be most readily distinguished by the colour pattern of the carapace. The carapace of *P. cygnus* is uniformly coloured and bears no obvious spots or markings (although the tips and ventral surface of some few spines are pale, the overall appearance nevertheless is uniform and unmarked). In *P. longipes* however, the carapace is brightly marked and spotted, the central region is darker than the anterior, posterior and lateral regions and in addition the carapace is marked by distinct pale spots distributed over it and the dorsal surface of supraorbital horns; there is also a longitudinal pale mark on the side of the carapace leading back from the post-antennal spine towards the cervical groove. A bow-shaped pale mark demarks the posterior margin of the dark central region. (Plate II, Figs. 3 and 4).

In addition to these colour markings, three morphological features, although variable, are useful in the separation of *P. cygnus* and *P. longipes*.

(a) In adults of both sexes of *P. longipes*, there are two sharp spines on the posterior margin of the thoracic sternum (Fig. 1j) whereas in *P. cygnus* adult females have no spines (Fig. 1f) and in males the two teeth are only poorly developed (Fig. 1e).

(b) The triangular Plate D of the first abdominal segment is fully divided by a vertical hairy groove in most *P. cygnus* (Fig. 1c) whereas in *P. longipes* it is usually not divided (Fig. 1i).

(c) *P. cygnus* usually has a band of setae across the posterior half of each abdominal tergum between the transverse groove and the posterior margin whereas in *P. longipes* only the first segment shows a band of setae. (Plate II, Figs. 2, 3 and 4).

There is one obvious difference between the specimens of *P. longipes* from Zanzibar and those from Japan and eastern Australia. This is in the colour pattern on the legs. The Zanzibar specimens have the dorsal surface of the merus of the legs ornamented with a thin white stripe which is interrupted along its length by three distinct white spots (Plate II, Fig. 4); the merus of the legs of the Japanese and eastern Australian specimens have an unbroken thin white stripe on the dorsal surface (Plate II, Fig. 3).

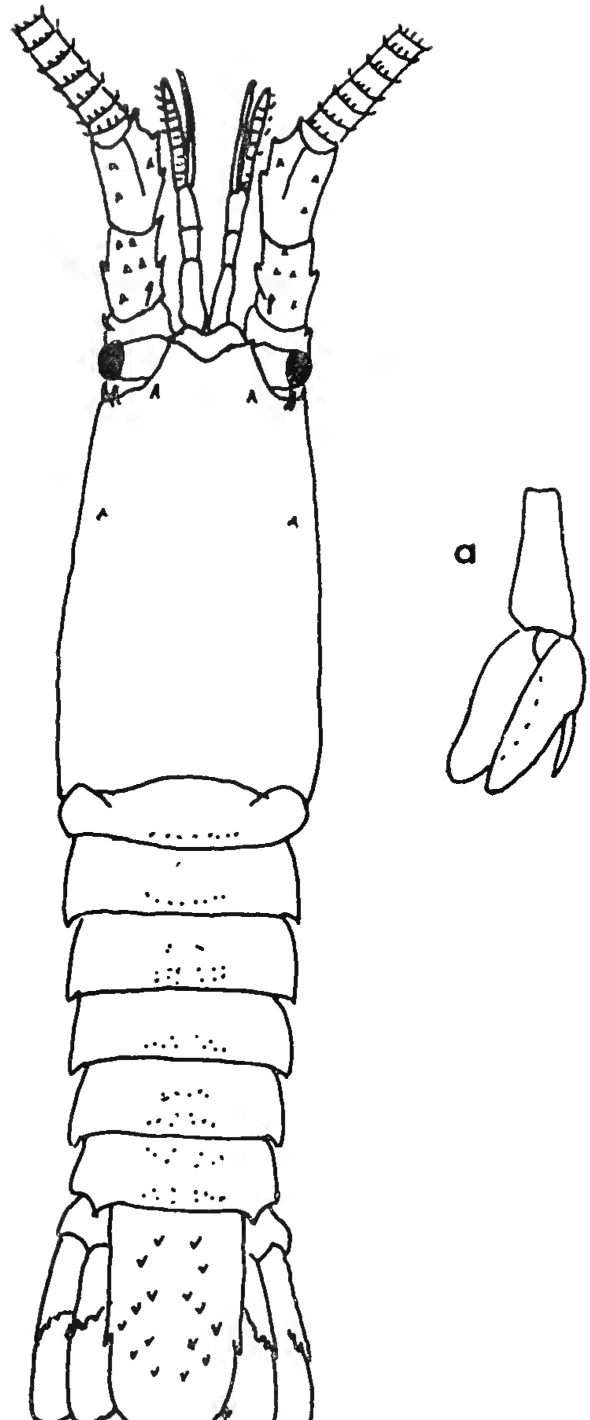

Fig. 2.—*Panulirus cygnus* sp. nov. puerulus stage 22.5 mm t.l., (a) pleopod, further enlarged and setae omitted.

Descriptions of Puerulus and Phyllosoma

Puerulus of P. cygnus (Fig. 2)

Thirty one specimens, (8 to 9 mm c.l., 21 to 24 mm total length) of the puerulus stage of *P. cygnus* are in the collection of the Western Australian Museum. (W.A.M. 66-58 to 68-58, 77-62 to 89-62) from the following localities: Maud Landing, Dirk Hartogs I., Abrolhos Is., Geraldton, Beagle I., Lancelin I., and Garden I. These were collected from craypots after they had fallen to the decks of crayfishing vessels. All were collected between the months of October and May.

Description.—Carapace dorso-ventrally compressed with two lateral carinae, each terminating anteriorly at a spine. Posterior half of carapace without spines, anterior region with one

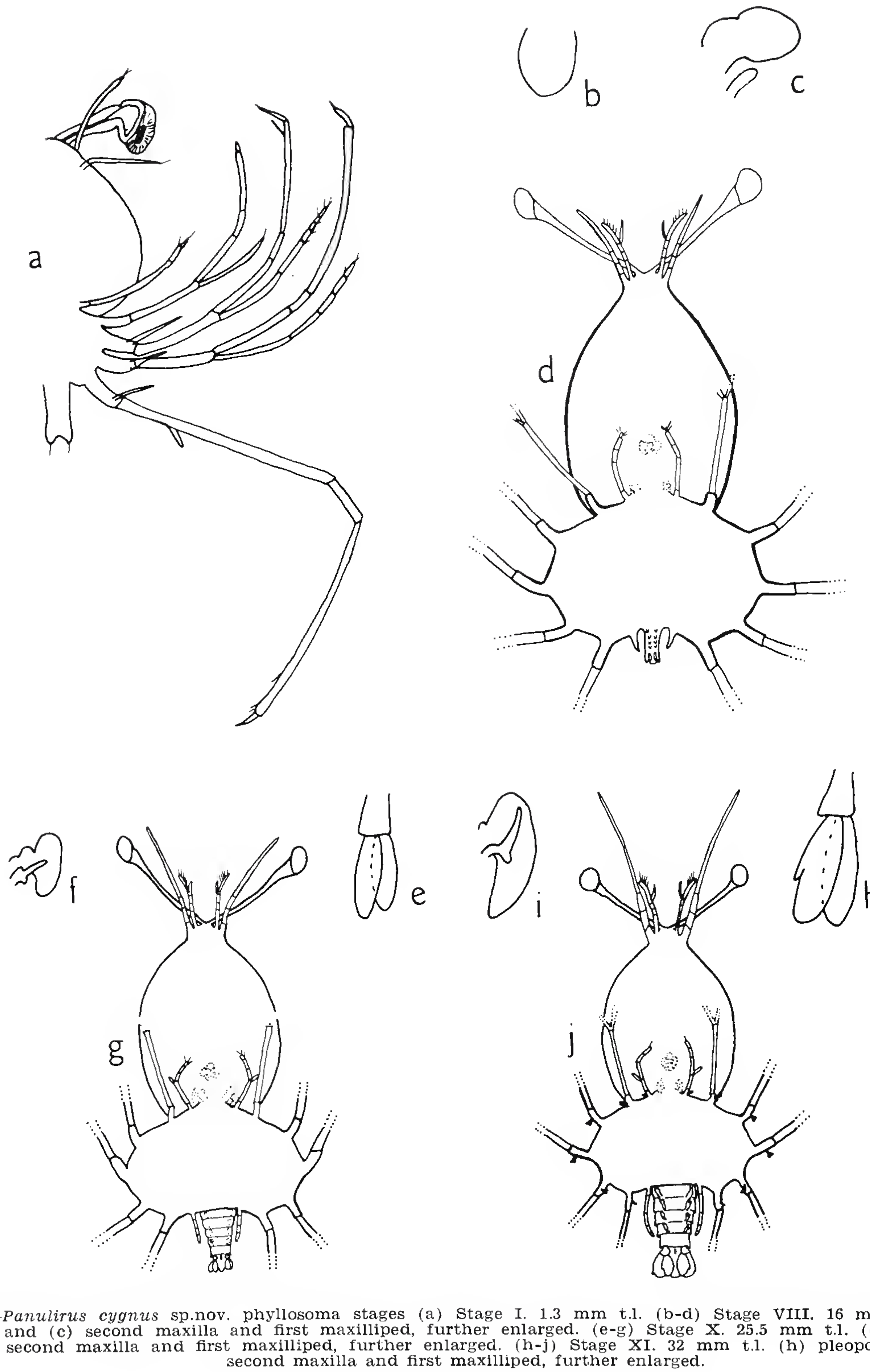

Fig. 3.—*Panulirus cygnus* sp.nov. phyllosoma stages (a) Stage I. 1.3 mm t.l. (b-d) Stage VIII. 16 mm t.l. (b) pleopod and (c) second maxilla and first maxilliped, further enlarged. (e-g) Stage X. 25.5 mm t.l. (e) pleopod and (f) second maxilla and first maxilliped, further enlarged. (h-j) Stage XI. 32 mm t.l. (h) pleopod and (i) second maxilla and first maxilliped, further enlarged.

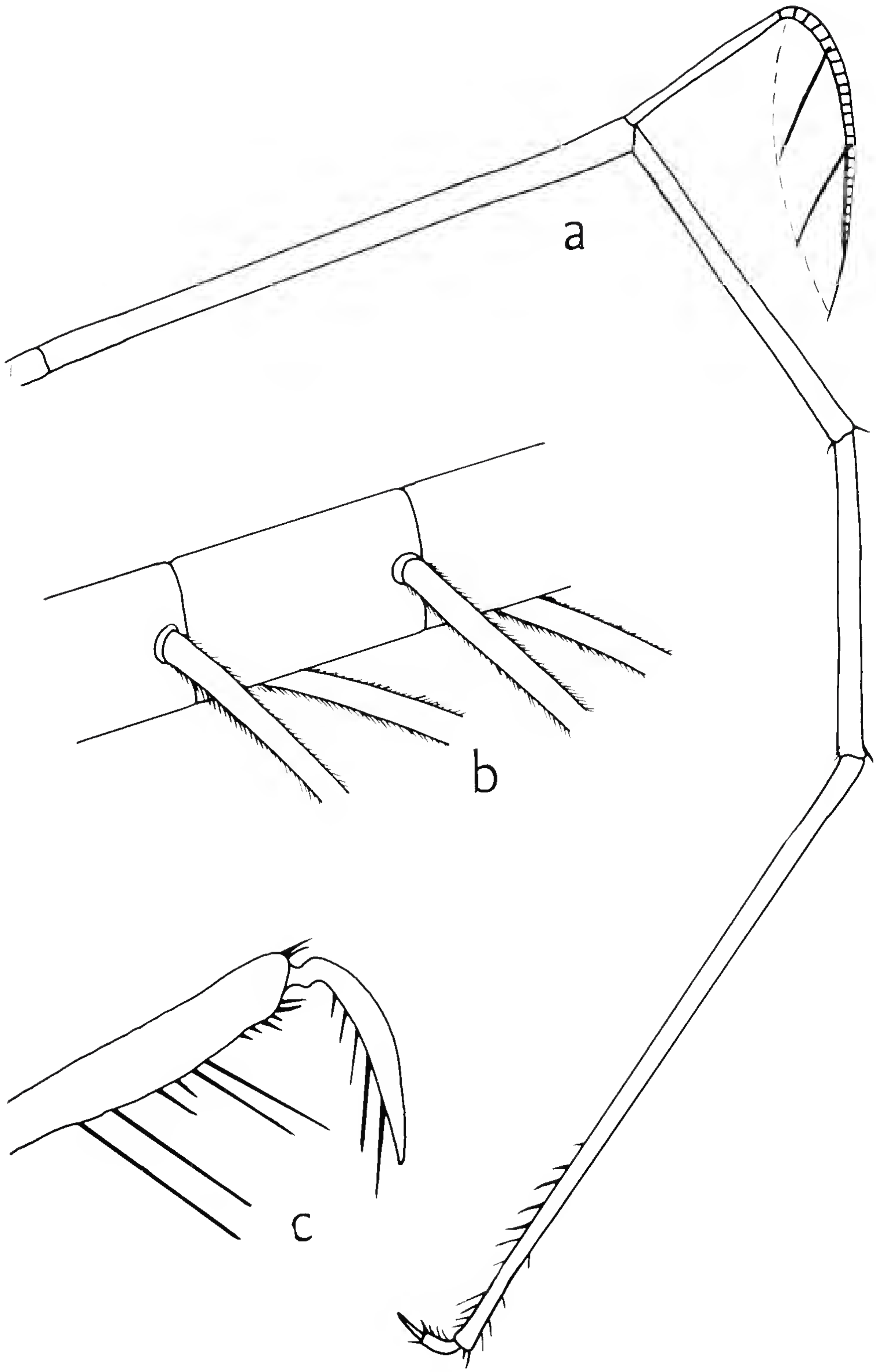

Fig. 4.—*Panulirus cygnus* sp.nov. phyllosoma Stage VIII (a) first pereiopod, only 3 satae of exopod represented, *c.* 5 x nat. size. (b) first pereiopod, detail of exopod segments and plumose setae, *c.* 35 x nat. size. (c) second pereiopod ?, distal portion of propodus and dactyl, *c.* 15 x nat. size.

pair of depressed conjoined supraorbital spines, one pair of spines behind these, one pair behind the eyes and one pair at antero-lateral angles of carapace. Antennae gradually tapered to tip, slightly longer than total length of body (antennae 1.02 to 1.14 times total length). Tergum of antennular plate small, without spines. Posterior margin of thoracic sternum smoothly concave without teeth.

Abdominal terga without transverse grooves; pleura of segments 2 to 6 terminate in single posteriorly recurved spines. Each pleopod biramous, setose along margins and with appendix interna on endopod.

Exopod of third maxilliped uniarticulate, extends at least to base of merus. Exopod of second maxilliped reaches distal end of carpus. Pereiopods more or less uniform in length, without trace of exopods.

Live specimens are transparent, preserved specimens opaque or light brown. Sexes at the puerulus stage are externally indistinguishable.

Phyllosoma of P. cygnus

A detailed investigation of the morphology and distribution of larval stages of *P. cygnus* has been commenced with the support of the Commonwealth Development Trust Fund and the co-operation of the State Fisheries Department. It is clear that a great extension to our knowledge will result from this investigation but the results will not be available for some time: in the meantime, preliminary descriptions of some stages are presented.

Eleven separate phyllosoma stages have been recognised for other species of *Panulirus* (e.g. Lewis 1951; Johnson 1956, 1960; Prasad and Tampi 1959). For *P. cygnus,* four separate stages (I, VIII, X, XI) are here described and the stage numbers which have been allocated to these specimens are assigned after comparison between these and the published descriptions of those other species.

Except for the first phyllosoma specimens which were recovered direct from a spawning female, all four late stage specimens were taken during the hours of darkness even though 37 daytime surface hauls were made compared with 22 night-time surface hauls over the two year sampling period.

Phyllosoma Stage I (Fig. 3a).—Several specimens of this first larval stage were obtained on two separate occasions; hatched from a captive egg-bearing female, and collected directly from the eggmass of another.

Description.—Body flattened, fore-body wider than hind-body, abdomen short and butted to hind-body. Antennae and antennules uniramous, each equal to total length of eye. Stalk of eye thick, unsegmented; eye large. Second maxilliped uniramous, third maxilliped with unsegmented exopod. First and second pereiopods with long coxal spine and segmented exopod. Third pereiopod with long coxal spine and short exopod bud. Total length 1.25 to 1.5 mm measured from anterior margin of fore-body to extremity of abdomen.*

* This measurement of phyllosoma is hereafter indicated by the abbreviation t.l.

When first hatched from the egg capsule, this first phyllosoma stage differs in some minor respects from the phyllosoma as described above. It is smaller (1.0 to 1.2 mm t.l.), globose, with the appendages and eyes closely folded against the body. The coxal spines and setae of the wrinkled and shorter legs are not apparent. It gives the general appearance of a somewhat "deflated" stage I phyllosoma.

Recently hatched specimens (presumably in this larval condition) were referred to by Sheard (1949) as "Naupliosoma" but here they are regarded as early phyllosoma stage I. These could rapidly develop into the condition described above by becoming turgid, thus increasing the size of body and legs, and extruding the spines on the coxae and on the exopodites of the pereiopods. The "naupliosoma" is not here regarded as a distinct stage separated by a moult.

Phyllosoma Stage VIII (Figs. 3b-d and 4).—A single specimen was collected in an N70 plankton tow net at surface 30 miles N.W. of Jurien Bay, W.A., on 3.ix.1957 at 0225 hours, W.A.M. 10-59.

Description.—Fore-body pear-shaped, narrower than hind-body. Antenna and antennule of equal length and two-third total length of stalked eye. Third maxilliped and first to fourth pereiopod with setose exopods (Fig. 4); fifth pereiopod present as a single joint. Second maxilliped without exopod. Appendages without gills or coxal spines. First maxilliped and second maxilla are shown in Fig. 3c. Abdomen parallel sided, unsegmented and butted to slightly concave margin of hind-body. Four pairs of pleopods present as simple lobes (Fig. 3b). Uropods free, bilobed without lateral spines. 16 mm, t.l.

Phyllosoma Stage X (Fig. 3e-g).—A single specimen was collected in an N70 plankton net at surface, 65 miles west of Fremantle, W.A., on 26.xi.1956 at 2300 hours. W.A.M. 8-59.

Description.—General body shape as for stage VIII. Antenna twice length of antennule and equal to total length of stalked eye. Third maxilliped and first to fourth pereiopods with setose exopods; fifth pereiopod uniramous, four jointed. Second maxilliped with small exopod bud. Appendages without gills. First maxilliped and second maxilla are shown in Fig. 3f. Abdomen segmented with four pairs of bifid pleopods (Fig. 3e). Uropods biramous with external lateral spine on each ramus. 25.5 mm t.l.

Phyllosoma Stage XI (Fig. 3h-j).—Two specimens were collected with the stage X specimen above. W.A.M. 7-59.

Description.—Antenna two and one half times length of antennule and one and one half times total length of stalked eye. Fifth pereiopod uniramous with four well defined segments. Second maxilliped with well defined exopod. Second and third maxillipeds and first to fourth pereiopods with two or more gills. First maxilliped and second maxilla are shown in Fig. 3i. Abdomen segmented with four pairs of biramous pleopods, showing rudiments of appendix interna (Fig. 3h). Uropods biramous, well developed, with external lateral spine on each ramus. 32 mm t.l.

Distribution of P. cygnus

P. cygnus occurs along the entire west coast of Australia from North West Cape (21°45'S.) to Hamelin Harbour (34°30'S.). The main fishing areas are between Shark Bay and Rottnest I. on the inner terraces of the Rottnest and Dirk Hartogs Shelf (see Carrigy and Fairbridge 1954 for definition of these terms). Animals are common in depths of 0-90 metres and specimens have been taken at 120 metres. During the day they shelter in the crevices and cavities of either reefs or coraline limestone, living coral or submerged aeolianite.

Other palinurid species occur only rarely in the range of *P. cygnus*. *Jasus lalandei* (Milne Edwards) 1837 is occasionally taken on the lower west coast (e.g. at Rottnest I. and Hamelin Harbour); in the northern part of the west coast (e.g. at North West Cape), *Panulirus versicolor* (Latreille) 1804, *P. ornatus* (Fabricius) 1798, *P. homarus* (Linnaeus) 1758, and *P. penicillatus* (Olivier) 1791 are known to occur.

The maximum and minimum water temperatures experienced in the area inhabited by *P. cygnus* are 27°C—the February maximum at North West Cape—and 16°C—the August minimum at Hamelin Harbour (Sverdrup *et al.* 1942). Vaughan (1940) recognised and named five water temperature zones and in accordance with his terminology, *P cygnus* inhabits the "subtropic temperature zone".

Feeding Habits of P. cygnus

P. cygnus is omnivorous, foraging at night on reefs, wave cut platforms and general areas adjacent to its daytime shelter. In January and February 1956, seventeen specimens were caught at Radar Reef, Rottnest I. while actively feeding on the reef flat at night. The stomachs were examined and these contained fragments of *Ulva* sp., *Lithothamnion* sp., annelids, sipunculids, small gastropods, small crustacea and echinoid spines. On one occasion, *P. cygnus* was observed eating the foot of the large limpet *Patellanax laticostata* Blainville 1825 in the shallow water on a reef flat.

Reproduction of P. cygnus

Mated females are readily recognised by the black butterfly-shaped spermatophore which covers the last two thoracic segments.

As far as is known, eggs are fertilized externally by spermatozoa which escape from the spermatophore. After fertilization, the orange eggs adhere in bunches to long filaments of the pleopods and females with eggs attached to these filaments have the surface of the spermatophore eroded. This erosion presumably allows the escape of spermatozoa at the time of fertilization and is almost certainly caused by the claw on the fifth leg of the female.

Recently mated females are first observed about July and in the Rottnest areas females with eggs beneath the abdomen are found during the summer months (November to February).

Once adult females have mated, they do not moult until the eggs on the pleopods have completed their development and the first stage phyllosoma have been released. Moulting of adult females occurs twice each year, just before mating (about June), and just after larval release (about March). Adult females examined in the field between July and February possess long filaments on the pleopods whereas those examined between March and June have very short filaments on the pleopods.

Acknowledgments

I wish to record my appreciation to the following persons who willingly gave me assistance during the course of this investigation: Dr. A. R. Main, Zoology Department, University of Western Australia for advice and encouragement; Dr. L. B. Holthuis, Leiden Museum for guidance on certain taxonomic problems; Mr. A. J. Fraser, Director of Western Australian State Fisheries Department for the provision of boat facilities; the Commonwealth Scientific and Industrial Research Organisation for financial assistance as a Post Graduate Student and also as an employee of the Fisheries Division; and Mr. G. Mack, Director of the Queensland Museum, Mr. F. McNeill of the Australian Museum and the many local and overseas collectors who provided essential research material.

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11.—Orientation and Composition of Plagioclase in a Basic Charnockite from Bunker Bay, Western Australia

By John G. Kay*

Manuscript received—19th June, 1962

Bunker Bay is an area of excellent coastal outcrop of high-grade metamorphic rocks. A clinopyroxene-orthopyroxene-hornblende-plagioclase granulite from the western shores of the bay is described, and attention drawn to the facts:

(i) the plagioclase grains are strongly oriented with *a*-axes parallel to the *b* tectonic direction.

(ii) the plagioclase grains belong to a population of variable composition that forms a normal distribution from An_{37} to An_{56}. A chemical analysis of the plagioclase is given.

Introduction

Cape Naturaliste is the northern limit of an elongate belt of Precambrian gneiss and granulite that extends sixty miles south to Cape Leeuwin (see Fig. 1). This "Leeuwin-Naturaliste Precambrian ridge" is an extension of the main Western Australian Precambrian Shield, from which it is separated by a belt of sediments, some 40 miles in width, that constitutes the southern part of the Perth Basin. Bunker Bay is situated two miles east of Cape Naturaliste, and marks the axial region of a large-scale north-plunging anticline, the nose of which forms the prominence of Cape Naturaliste.

Published references to Cape Naturaliste have described the geology in broad outline only. Saint-Smith (1912) in the course of a comprehensive areal survey recognised the general rock types and their fundamental relationships as a Precambrian granite-gneiss basement overlain in part by limestone. Woodward (1916) mentioned some tectonic aspects of the area, and Aurousseau (1926, p. 625) commented on Bunker Bay in these terms: "The exposures at Bunker Bay are admirable and should attract the attention of a student of metamorphism who wishes to make an intensive study of a small area. None could be more suitable than Bunker Bay." Prider (1952 and 1955) considered the Cape Leeuwin-Cape Naturaliste Precambrian belt to be the southern part of a more comprehensive "Leeuwin-Greenough Block", which, in relation to the remainder of the Western Australian Shield constituted the "West Coast Province."

A detailed investigation was recently undertaken by the present author and the results of this work are the substance of a forthcoming paper. The following is a summary of the main features. The basement rocks are a succession of gneisses and granulites of highly variable mineralogy. The dominant rocks are poorly fissile, and range from granitic through adamellitic to granodioritic in bulk mineralogical composition. Mafic components are one, or a combination of two or more of hornblende, biotite, orthopyroxene, clinopyroxene, garnet, and very rarely, fayalite. Interbanded with these rocks are bands of basic granulite typically containing the assemblage hornblende-clinopyroxene-plagioclase or hornblende-clinopyroxene-orthopyroxene-plagioclase. The overall succession probably represents a sedimentary pile with concordant and possibly some discordant basic igneous rocks that has undergone regional metamorphism. This has produced rocks of granulite and upper almandine-amphibolite facies, with some evidence that the latter facies has developed by downgrading of the former.

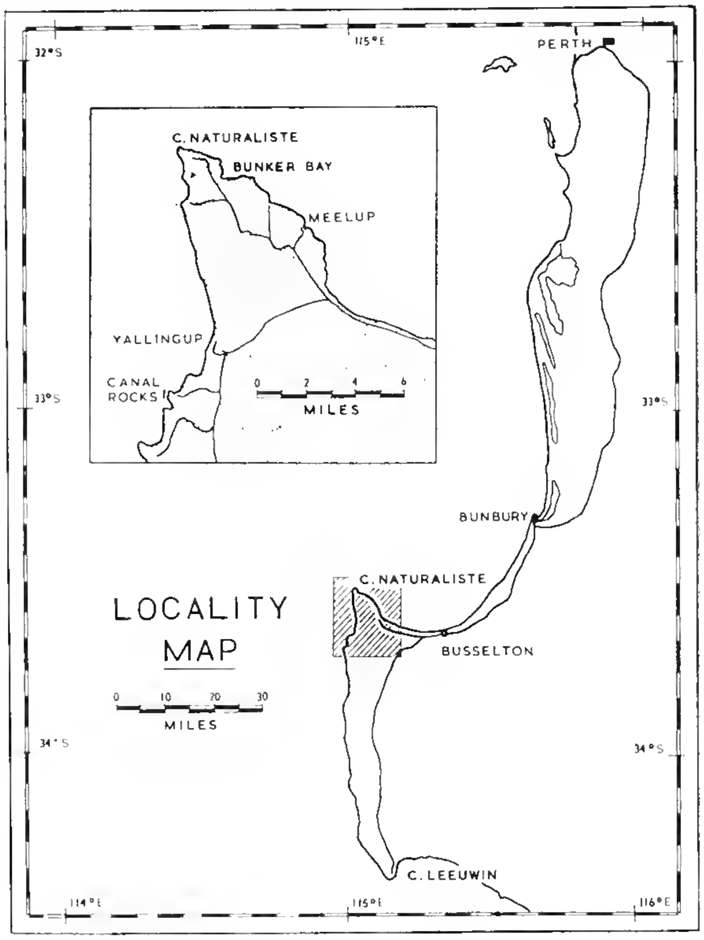

Fig. 1.—Locality Map.

The rocks contain a foliation which is more likely a consequence of isoclinal folding than a relict pre-metamorphism feature. This foliation is warped into large-scale folds plunging north and overturned to the west. Linear structures are present and these essentially parallel the axes of associated drag folds. The lineation plunges 20°-40° in a direction that varies from north-east to 20° west of north. At Bunker Bay the lineation consistently plunges 30°-37° in the direction 350°.

Following prolonged erosion, the basement rocks have been lateritized and later covered on their western flank by a varying but appreciable thickness of aeolian Quaternary calcarenite. This forms part of the Coastal Limestone of Western Australia, and has been described by Fairbridge and Teichert (1953, pp. 68-87).

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Petrography

The remainder of this paper sets out the results of a detailed investigation of plagioclase from basic granulites, 39407* and 39409, from Bunker Bay. These rocks outcrop as two closely spaced parallel bands, each several yards in width, extending into the western waters of the Bay. Specimen 39407 is representative of the southern band, and 39409 of the northern band. At low tide and after prolonged sand scour the two bands can be seen to form a single U-shaped mass with a joining segment that in part transgresses the surrounding foliation. Outcrop boundaries of the two bands strike 77° and dip 33°-37° N, and parallel the foliation of surrounding garnetiferous, biotitic and hornblendic gneiss.

Specimen 39407 is an almost black rock, of somewhat "greasy" appearance, with medium-grained saccharoidal texture, and devoid of obvious mineralogical banding. A well-developed preferred orientation of hornblende and pyroxene prisms plunges 33° in the direction 350°. This lineation lies within, and parallel to the dip of a poorly developed foliation. Thin veins of hornblendite traverse the granulite, and many of these strike 67° and dip 70° S.

In thin section specimen 39407 is seen to have a xenomorphic granular texture with a strongly oriented fabric of the ferromagnesian minerals and plagioclase. The mineralogy of the rock is:

Plagioclase (40.1% †)—andesine, An_{45}‡; generally in anhedral, equi-dimensional grains between 0.25 mm and 0.5 mm in diameter; non-antiperthitic and unzoned; $2V/\gamma = 80°$; albite and acline twinning well developed; inclusions of euhedral apatite; *a*-axes strongly oriented (see Fig. 2); extinction $X' \wedge 010$ in sections $\perp a = 24.0° \pm 5°$ (see Fig. 4).

Hornblende (27.6%)—as anhedral grains, in cross section 0.3 mm x 0.3 mm and commonly 1 mm in length; *c*-axes show distinct orientation, and the fabric of 200 grains is shown in Fig. 3; strongly pleochroic in shades of brown, with $\alpha =$ mid yellow-brown, $\beta =$ very deep brown, $\gamma =$ very deep brown; $\alpha < \beta = \gamma$, $\beta = 1.680 \pm 0.003$; $2V/\alpha =$ approximately 80°; $\gamma \wedge c = 20°$.

Orthopyroxene (16.9%)—ferrohypersthene, Fs_{52}; generally as anhedral grains 0.25 mm x 0.25 mm; distinctly pleochroic with $\alpha =$ pale pink, $\beta =$ pale yellow, $\gamma =$ pale aqua-green; $\gamma = 1.730 \pm 0.002$; $\alpha = 1.714 \pm 0.002$; $\gamma - \alpha = 0.016$; $2V/\alpha = 52° \pm 1°$.

Clinopyroxene (11.0%)—salite Wo_{48} En_{33} Fs_{19}; similar in habit to ferrohypersthene, pale yellow-green and faintly pleochroic $\gamma = 1.719 \pm 0.003$; $2V/\gamma = 56.5° \pm 0.5°$; $r > v$ (weak); $\gamma \wedge c = 42°$.

Iron Ores (4.4%)—(undifferentiated); as small anhedral grains throughout the rock; in part showing minor leucoxenization.

Apatite is a minor accessory, and occurs in small discrete anhedra, and as rare scattered inclusions in the plagioclase. K-feldspar, quartz and zircon are absent.

The secondary hornblendic bands contain amphibole optically similar to that in the enclosing granulite, i.e. pleochroic with $\alpha =$ mid brownish yellow, $\beta =$ very deep brown, $\gamma =$ very deep brown, $\alpha < \beta = \gamma$; $\gamma = 1.703 \pm 0.003$, $\alpha = 1.685 \pm 0.004$; $\gamma - \alpha = 0.018 \pm 0.007$.

The granulite is cut by small tabular pegmatites of secretion origin. These are rather discontinuous, and normally less than 3 inches thick. Plagioclase is the dominant mineral—forming approximately 80% by volume and determined optically as andesine, zoned somewhat irregularly from An_{45} at the centres of grains to An_{30} at the margins. Quartz and untwinned microcline occur as interplagioclase fillings. Hypersthene (Fs_{35}) is present to the extent of 5%, and clinopyroxene frequently forms a margin to the pegmatites. An interesting accessory is zircon; interesting because of its absence from the studied samples of enclosing granulite. Zirconium has apparently concentrated into the secreted pegmatitic phase.

Specimen 39409 conforms in general to the description for 39407. In detail, however, the plagioclase (andesine, An_{45}; 47.8%) and orthopyroxene (ferrohypersthene, Fs_{52}; 18.5%) content is greater than in 39407, the hornblende (14.7%) content is considerably lower, and the clinopyroxene ($En_{36.5}$, Fs_{21}, $Wo_{42.5}$; 11.9%) content is similar.

Aurousseau (1926, p. 624) published a brief account of a "hornblende-orthopyroxene-plagioclase amphibolite" from Bunker Bay, and included a chemical analysis of the specimen. Although an exact field location for the analysed rock is not given, there can be little doubt that the sample was taken from the granulite (39407 or 39409) described in this paper. The C.I.P.W. norm for Aurousseau's analysed rock is given by Wilson (1958, p. 76).

Orientation of Plagioclase

The plagioclase grains in basic granulites from Cape Naturaliste possess a strongly preferred orientation. Evidence of this is the disproportionate abundance of grains approximately parallel to 100 that are revealed in thin-sections cut normal to the *b*-lineation. In order to investigate this fabric, the *a*-axis position for each of 200 grains of plagioclase in a thin-section from specimen 39407 was determined using a 4-axis universal stage. Fig. 2 is a reproduction of the fabric diagram obtained, and shows a well-developed orientation of *a*-axes with an average plunge of 20° in the direction 350°.

A similar analysis was carried out on the attitude of c-axes for 200 grains of hornblende from the same thin-section. The result is shown in Fig. 3, which indicates a strong mean alignment plunging 20° in the direction 348°. The similarity of the fabrics in Figs. 2 and 3 is striking.

* The specimens are catalogued and housed in the rock collection of the Department of Geology, University of Western Australia.

† All such percentages are volume percentage obtained from parallel line traverses on section cut normal to lineation.

‡ Mineral compositions were estimated by reference to the following graphical data: for plagioclase, Winchell and Winchell (1951, p. 283); for orthopyroxene, Hess (1952); for clinopyroxene, Hess (1949, p. 634).

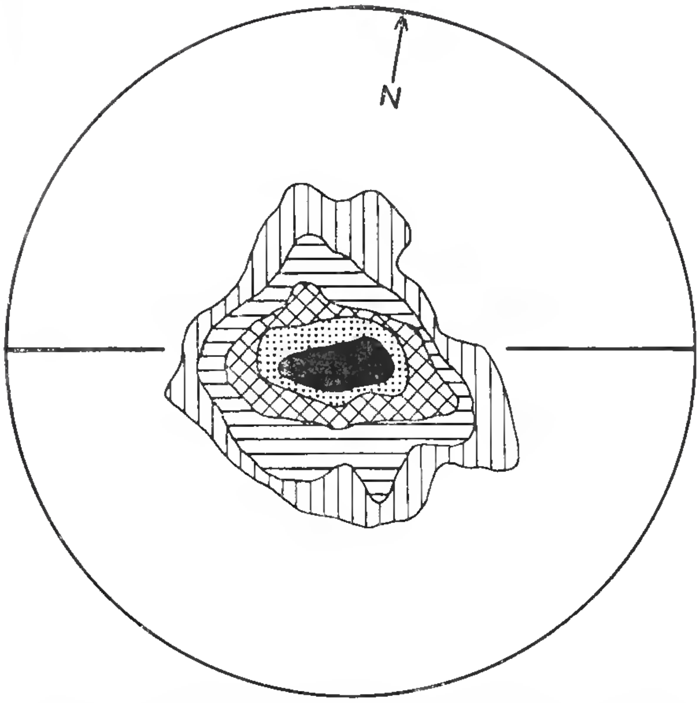

Fig. 2.—Orientation diagram of 200 andesine a-axes from 39407. The fabric is a linear orientation plunging 20° on an azimuth 350°. Contours at 1%, 3%, 5%, 10%, 15% (including 16.5% maximum). The horizontal line represents a plane, strike 80°, dip 15° N.

Specimen 39407 is strongly lineated in a macroscopic sense due to alignment of prismatic minerals, in particular, hornblende. Throughout the Cape Naturaliste area such lineations parallel drag fold axes and can thus be taken as b-lineations. The lineation in specimen 39407 is not accompanied by drag folds, but in view of the relationship existing elsewhere is clearly a b-lineation.

It may be concluded that in this rock the a-axes of plagioclase have preferentially aligned during metamorphism parallel to the c-axes of hornblende and thus parallel to the b-tectonic direction. The direction of preferred orientation of the plagioclase a-axes defines a b-lineation. This same conclusion was reached for rocks in the Ornö Huvud by Wenk (1937).

The macroscopic lineation of 39407, measured on the poorly developed foliation, plunges 33° in the direction 350°. A plunge discrepancy of 13° is thus apparent between the b-lineation as measured in the field and measured by petrofabric methods. This discrepancy may indicate that the foliation on which field measurements were made is not the true a - b plane, but may also mean no more than the sum of sampling and experimental errors.

Extinction in sections normal to a

During the fabric analysis of plagioclase in specimen 39407, extinction values $X' \wedge 010$ in sections normal to a were obtained for 200 grains. Fig. 4 is a plot of extinction values ($X' \wedge 010$ in section $\perp a$) against percentage of readings. The result conforms to a somewhat skewed normal distribution around a mean of 24° - 25°, but with a spread from 20° to 30°. This range corresponds to a variation from andesine An_{37} to labradorite An_{56}, with a mean at approximately andesine An_{45}. Although most readings are close to the mean, a significant number depart from the mean by amounts outside the limits of experimental error (estimated to be less than $\pm$ 2°). This serves to emphasise that in the course of normal petrographic investigations the use of a single extinction measurement to establish bulk plagioclase composition could lead to considerable error. The difficulty also extends to other isomorphous groups such as the pyroxenes, and should be taken into account when assessing the value of data obtained from single grains.

TABLE I

Analyses of plagioclase from Bunker Bay

	I	II
SiO_2	55.01	55.55
Al_2O_3	29.14	28.41
(Fe_2O_3, FeO) as Fe_2O_3	0.16	0.02
CaO	9.01	9.53
MgO	Nil	Nil
SrO	0.18	0.10
K_2O	0.27	0.66
Na_2O	5.63	5.73
H_2O+	0.23	Nil
	99.63	100.00

I. Bulk plagioclase from 39407, Bunker Bay, W.A.
II. Bulk plagioclase from 39409, Bunker Bay, W.A.
Anal. J. G. Kay and I. D. Martin.

A chemical analysis of the bulk plagioclase from 39407 is presented in Table 1 (column 1). In terms of end-member composition calculated using standard formulae, the feldspar is

	%
albite	47.63
anorthite	44.69
K-feldspar	1.59
"Sr-feldspar"	0.56
	94.47

The composition determined chemically and expressed as anorthite per cent. ($An_{44.7}$) agrees very well with the mean composition determined optically by the method $X' \wedge 010$ in section $\perp a$ (An_{45}).

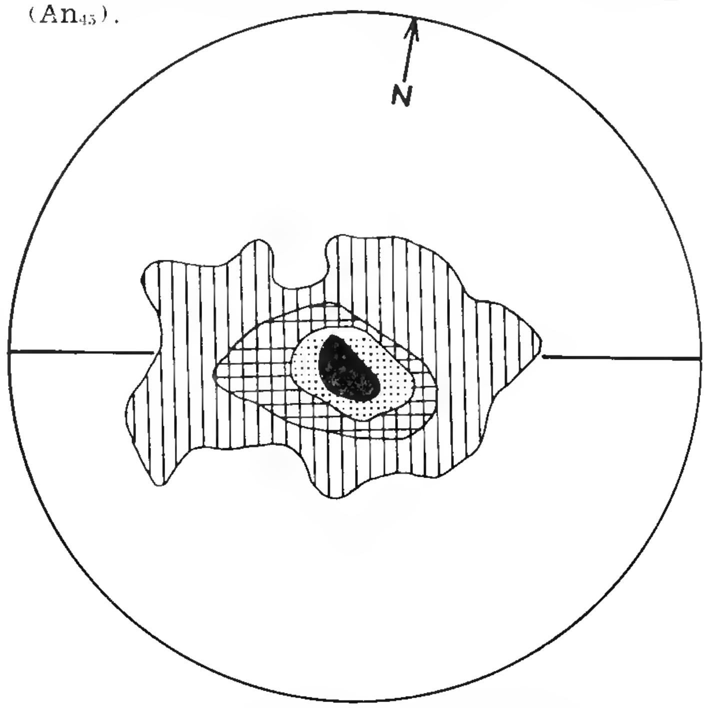

Fig. 3.—Orientation diagram of 200 hornblende c-axes from 39407. The fabric is a linear orientation plunging 20° in the direction 350°. Contours at 1%, 5%, 10%, 15% (including 17.5% maximum). The horizontal line represents a plane, strike 80°, dip. 15° N.
Rare grains (not shown) have c-axes approximately normal to the indicated linear maximum.

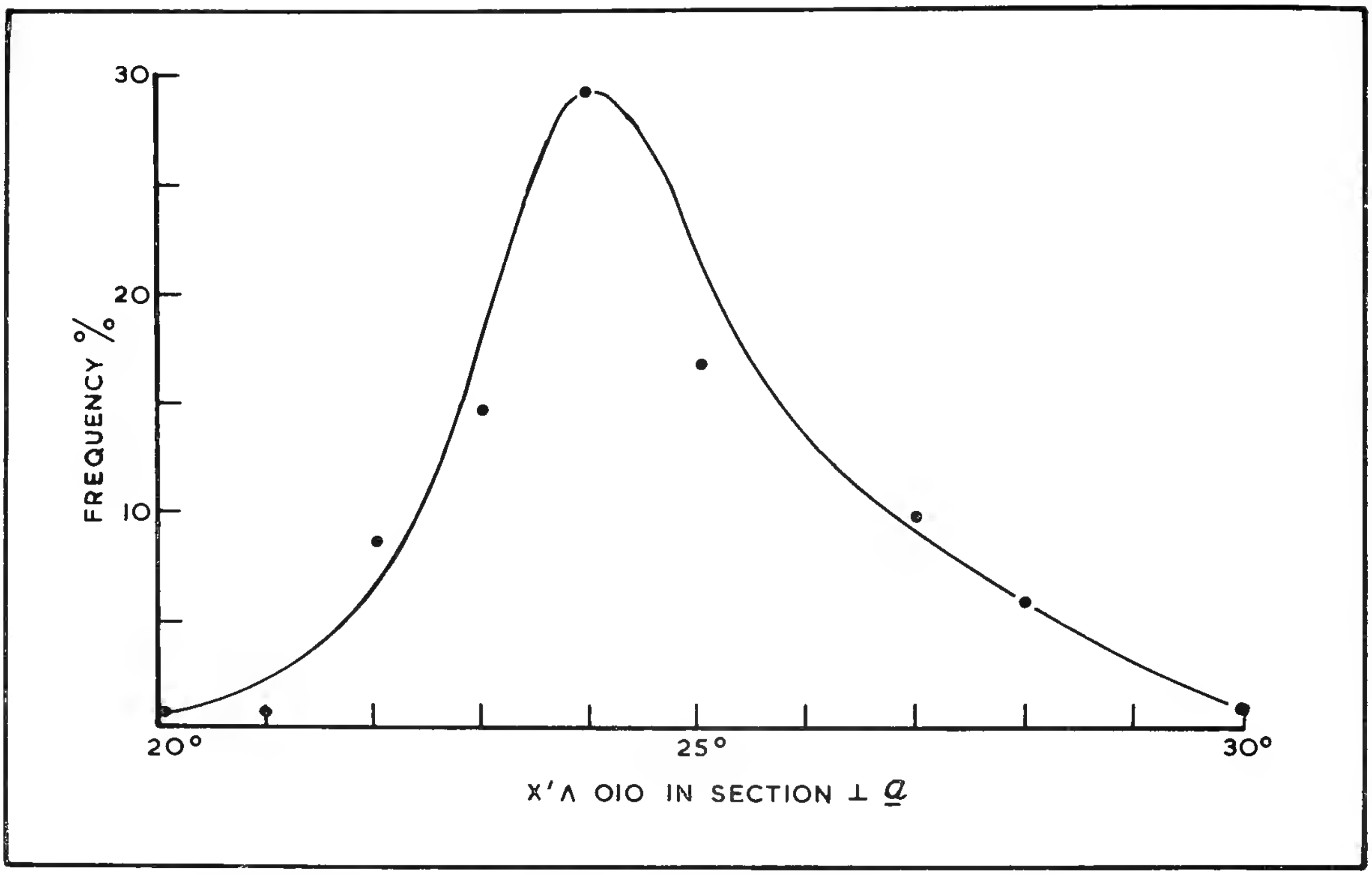

Fig. 4.—Graph showing the frequency of readings for the extinction X′ ∧ 010 in section normal to *a* for 200 andesine grains in 39407. Values range from 20° to 30°, but with a strong maximum near 24°.

The deficiency of 5.53% revealed by end-member summation is a problem in view of the apparent purity of the analysed sample. This deficiency was initially attributed to incorrect alkali determinations, but a check analysis indicated no significant error. Furthermore, after satisfying the end-member requirements, there is a surplus of 3.03% Al_2O_3 and 1.71% SiO_2. These, together with the Fe_2O_3 and H_2O of the analysis may indicate undetected alteration products and/or inclusions.

An analysis was also carried out on plagioclase from specimen 39409, a rock which is mineralogically and texturally very similar to 39407. The plagioclase of 39409 (Table 1, column II) responds more satisfactorily to end-member summation:

	%
albite	48.48
anorthite	47.27
K-feldspar	3.90
"Sr-feldspar"	0.31
	99.96

For this analysis Al_2O_3 exceeds by 0.86% the amount required to fulfil end-member requirements, whereas the available SiO_2 is 0.82% less than the amount required. Using the method X′∧010 in section ⊥ *a*, the average composition for this plagioclase was determined as andesine An_{45}.

Acknowledgments

I would like to thank Mr. I. D. Martin who assisted with the chemical analysis of the plagioclase. Professor R. T. Prider and Dr. G. J. H. McCall read the manuscript and offered helpful suggestions. The work was carried out during the tenure of a Hackett Scholarship at the University of Western Australia.

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12.—Origin of Glauconite in some Sandstones of the Plantagenet Beds, Cheyne Bay, Western Australia

By E. A. Hodgson*

Manuscript received—19th June, 1962

The spicular sandstones of the Plantagenet Beds are composed mainly of quartz, glauconite, sponge spicules and opaline cement. Much of the glauconite is associated with muscovite and all variations between pure muscovite, muscovite with incipient developments of glauconite, and pure glauconite can be seen. X-ray powder patterns of the pure "end members" show that they are structurally very similar. Studies of the vertical variation of percentage composition of the rocks suggest that at least some of the glauconite of the sandstones has formed from muscovite, probably during early diagenesis.

Introduction

Various theories of origin have been postulated for glauconite. It has been suggested that glauconite forms from mud, especially in the presence of organic matter (Murray and Renard 1891), from coprolites (Takahashi and Yagi 1929), from the flocculation of colloidal solutions (Hadding 1932) and from biotite (Galliher 1935, 1939). Much of the extensive literature on the subject is listed in bibliographies by Cloud (1955) and Wermund (1961). The following short paper describes the occurrence and probable origin cf glauconite in the Eocene Plantagenet Beds at Cheyne Bay, Western Australia.

Discussion

The Plantagenet Beds were described by Clarke and Phillipps (1955) and more recently have been the subject of investigation near Cheyne Bay by Hodgson, Quilty and Rutledge (1962). At Cheyne Bay, they are represented by at least 250 feet of well-banded, glauconite-bearing, spicular sandstone. The banded nature of the rocks is due to the alternation of hard spicular opal-rich layers and softer less siliceous ones. Mineralogically the spicular sandstones are simple, being composed almost entirely of quartz, sponge spicules (and associated opaline cement) and glauconite with minor amounts of muscovite, clay minerals, magnetite and pyrite.

The sandstones rarely contain more than 10 per cent. glauconite and the amount seems unrelated to the hardness of the rocks in which it is found. The glauconite generally occurs either as minute (0.05 mm) globules associated with muscovite, or as small rounded aggregates between 0.1 mm and 0.05 mm across. The latter frequently contain remnants of muscovite. Foraminiferal tests infilled with glauconite are not commonly found in these rocks.

In reflected light the glauconite is olive-green but is a somewhat lighter colour in transmitted light. Where limonitization is advanced the colour becomes yellowish. Since the individual crystals are extremely small and are randomly oriented, the grains show no pleochroism and only aggregate birefringence. Accordingly the refractive indices cannot be determined precisely, but fall within the range between 1.615 and 1.630.

From grain mounts of the "lights" of the spicular sandstone, it is possible to select a series of specimens ranging from glauconite-impregnated muscovite to almost pure glauconite. Apparently at least some of the glauconite in the rocks has formed from muscovite. A comparatively early stage in the formation of glauconite from muscovite is represented by grains of the latter in which glauconite globules occur along the 001 cleavage planes around the edges of the flake (Fig. 1). Where glauconitization is slightly more advanced, the developing globules can be seen throughout the muscovite flake. An even later stage is represented by almost pure glauconite grains which have a micaceous habit. No doubt much of the glauconite which now shows no feature relating it to muscovite, has been derived from this mineral.

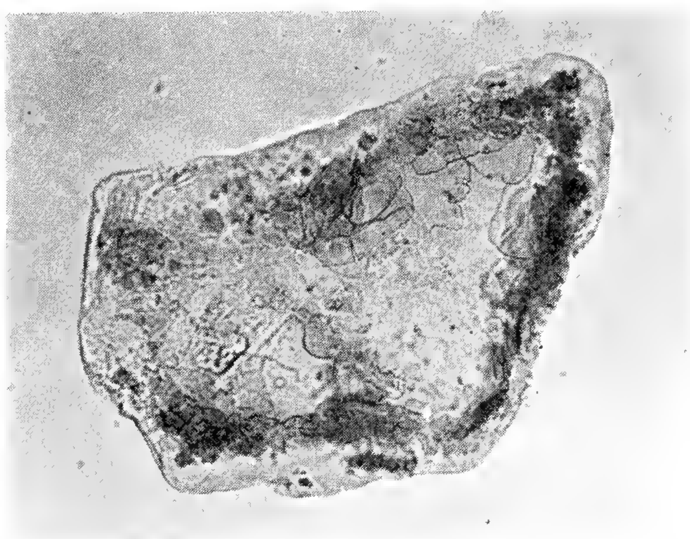

Fig. 1.—Muscovite flake from U.W.A. Specimen 46759. Plane polarized light. Glauconite is developing along the 001 cleavage planes around the periphery of the flake. Width of field of view 0.15 mm.

Supporting the theory of biotite-glauconite transformation, Galliher (1939) cited the presence of reaction structures in the biotite of the sediments of Monterey Bay, California. In addition he mentioned the work of Gruner (1935) which, using X-ray powder patterns, showed that glauconite was structurally related to the

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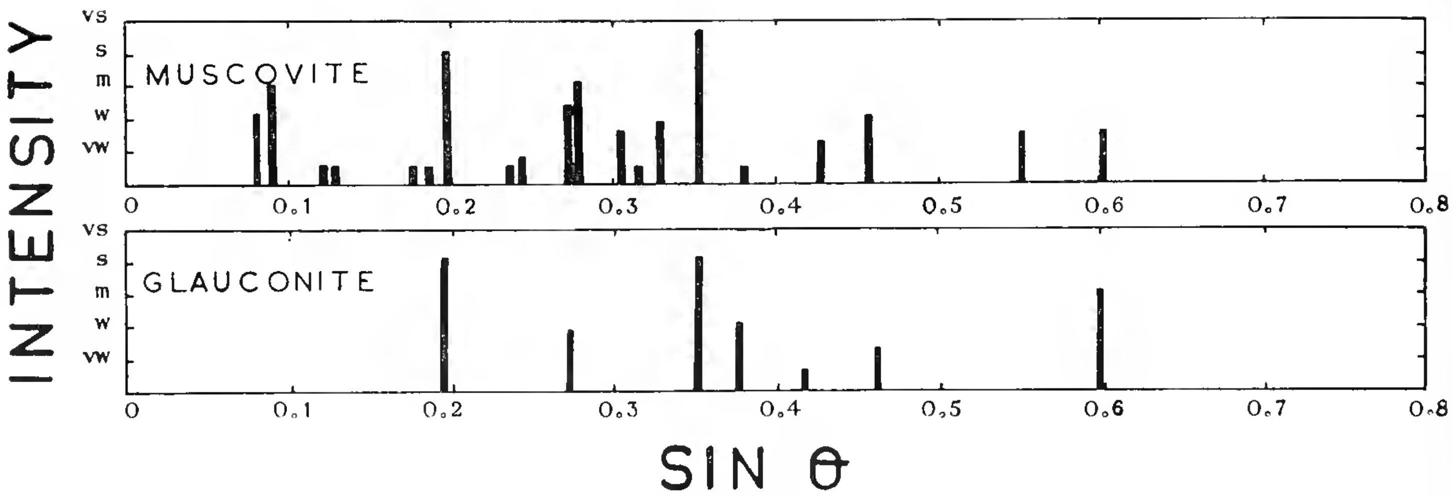

Fig. 2.—Graph showing the X-ray powder patterns of glauconite and muscovite from U.W.A. Specimen 46759. The pattern of muscovite has many weak reflections not present in the glauconite pattern because of diffusion.

micas. In the present investigation hand-picked samples of glauconite and muscovite were X-rayed by the powder method. The overall similarity of the patterns (see Fig. 2) suggests that the glauconite of the spicular sandstones is structurally similar to the muscovite from which it is presumed to have formed. Many weak lines in the mica pattern are not present in the pattern produced by the glauconite. Gruner noted this in his work and concluded that such lines are absent in the glauconite pattern because of diffusion.

The vertical variation of composition of the sandstones shows that quartz and glauconite percentages vary in sympathy. Presumably an increase in the amount of quartz reflects an increase in the influx of detritals (including muscovite) into the bottom sediment. The additional mica due to such influxes would permit more glauconite to form than would do so otherwise.

Conclusions

The structural similarity of glauconite and muscovite is illustrated by the similarity of the powder patterns produced by pure samples of the minerals.

Reaction structures show the direct nature of the transformation of muscovite to glauconite. Studies of variations of percentage composition in vertical sections support the view that glauconite forms directly from muscovite.

Though much of the glauconite in the rocks has formed from muscovite, presumably during early diagenesis, it is not possible to say that all the glauconite formed in this manner. It is conceivable that some owes its origin to processes quite unrelated to those mentioned above.

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13.—A record of Foraminifera from Oyster Harbour, near Albany, Western Australia

By K. G. McKenzie*

Manuscript received—20th March, 1962

One hundred and thirty-four species of foraminifera from Oyster Harbour are identified, and a partial synonymy, together with a brief discussion, is given for each species.

Occurrences are recorded by samples in a table as percentages of total foraminifera populations, sample locations being shown on a map.

An indication is given of the ecological significance of this microfauna.

Introduction

Although several shallow water faunas of foraminifera have been described from the Southern Ocean off south-eastern Australia (Parr 1932*a*, 1932*b*, 1945, 1950; Chapman 1941), Western Australian records of similar faunas are rare (Chapman and Parr 1935; Parr in Fairbridge, 1950; Logan 1959), and are practically non-existent for the south coast west of Longitude 124° 40′ E. In this paper the foraminiferal fauna of one hundred and twenty sediment samples from Oyster Harbour, a drowned estuary near Albany, Western Australia, is described.

The samples were collected during March 1960, from the shore and bottom of the Harbour, at depths up to forty-four feet (over seven fathoms), which was the maximum depth recorded in the Harbour. A grab sampler was used for all bottom samples.

Sample locations were fixed either by taking compass bearings from the stations to several prominent points around the Harbour and reversing these bearings when plotting stations on the map, or by direct plots from aerial photographs (Figure 1).

The samples were prepared either by dry-sieving portions of 50g dry weight in a Rotap machine for ten minutes, or by wet sieving. Of the resultant fractions only those retained on the 115 Tyler sieve (125 microns) and coarser sieves were examined, experience having shown that the finer fractions contained few indentifiable foraminifera.

Generally, between one hundred and two hundred specimens were counted per sample. In four samples, however, no foraminifera were found, and in some others the faunas were so impoverished that it was not possible to count this number of specimens. In other cases, where samples were rich in foraminifera, larger counts were made. The abundance of each species recorded in a sample was calculated as a percentage on the basis of the number of specimens counted in that sample. In calculating these percentages, an accuracy of better than one percent was not considered significant, and the letter "t" was used for fractions less than this. For some samples exaggerated percentages were obtained due to the paucity of the fauna (Table I).

As the source area of the Oyster Harbour sediments includes rocks of Eocene age, the possibility exists that part of the material dealt with in this paper is fossil. Such fossil specimens however, if present, could be expected to appear more worn than living ones, but the only specimens showing signs of wear in Oyster Harbour are those from near the southern entrance, where such attrition is explained by movement back and forth in response to tidal forces where these are greatest.

Synonymy and Discussion

The beautifully-figured monographs of Brady (1884) and Heron-Allen and Earland (1915), provide valuable guides to the identification of the species; and to ensure that the nomenclature was up to date the author consulted Thalmann (1932), Ellis and Messina (1940 *et seq.*) and other available literature. Since the submission of this paper the author has been able to consult Barker (1960), and has brought the nomenclature into line with this reference, as indicated in the text. The changes made should be considered when consulting the Table where they have not been incorporated.

In Table I the species are placed in families according to the classification of Loeblich and Tappan (1961). The order of species in the Table is that followed below.

A partial synonymy is given for each species, restricted to the original record and others which, when possible, refer to an occurrence of the species in southern Australian waters. The original records are cited fide Ellis and Messina (1940 *et seq.*).

A brief discussion, dealing with the distribution of the species in southern Australian waters, where this is known, and in some cases extending to the environment it favours and other data of interest, follows the synonymy of each species.

Glomospira gordialis (Jones and Parker)

Trochammina squamata Jones and Parker var. *gordialis* Jones and Parker 1860, p. 304.

Ammodiscus gordialis (Jones and Parker); Brady 1884, p. 333, Plate XXXVIII, Figs. 7-9; Heron-Allen and Earland 1915, p. 618, Plate XLVI, Fig. 26.

Glomospira gordialis (Jones and Parker); Thalmann 1932, p. 300.

The Oyster Harbour specimens agree well with Brady's figures. It is noted that Brady only records the species from depths in excess of

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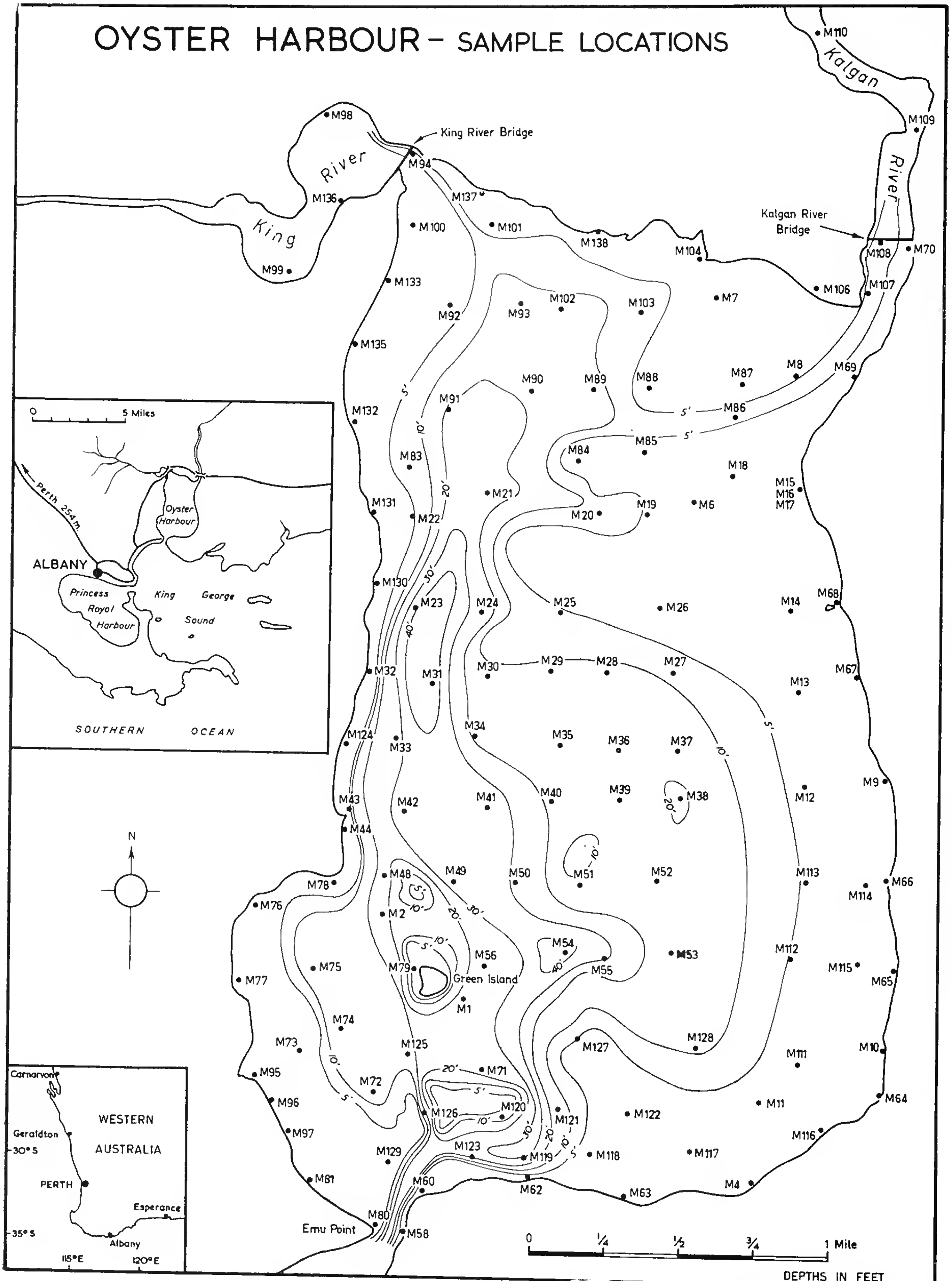
OYSTER HARBOUR – SAMPLE LOCATIONS
King River Bridge
King River
Kalgan River
Kalgan River Bridge
Green Island
Emu Point
DEPTHS IN FEET
0 ¼ ½ ¾ 1 Mile
ALBANY
Oyster Harbour
Princess Royal Harbour
King George Sound
SOUTHERN OCEAN
Perth 254 m
5 Miles
WESTERN AUSTRALIA
Carnarvon
Geraldton
PERTH
Esperance
Albany
30° S
35° S
115° E
120° E

Fig. 1

50 fathoms whereas at Oyster Harbour it occurs in a single shore sample. However, it is recorded from shallow water (5-10 fathoms) in the Kerimba Archipelago, off the eastern coast of Africa, between latitude 10° 40′ S. and latitude 13° 00′ S.

Miliammina fusca (Brady)

Quinqueloculina fusca Brady 1870, p. 286.
Miliolina fusca (Brady); Heron-Allen and Earland 1915, p. 576.

This small species is common in shallow water brackish environments. The siliceous test determines the transfer of this species to the genus *Miliammina*.

Miliammina sclerotica (Karrer)

Quinqueloculina sclerotica Karrer 1868, p. 152, Plate III, Fig. 5; Cushman 1929, p. 24, Plate I, Fig. 5 a-d.

The specimens from Oyster Harbour resemble Cushman's figures. This species also is transferred to *Miliammina* because of its siliceous test.

Miliammina sp.

Test small, siliceous, sub-circular in outline, rather compressed; coiling milioline, the later chambers broader than the earlier ones; aperture rounded with a small pointed tooth. One specimen.

Reophax scorpiurus Montfort

Reophax scorpiurus Montfort 1808, p. 331, text-fig. p. 330; Chapman and Parr 1935, p. 3; Chapman 1941, p. 191.

Distributed along the southern coast from south-east Australia to Oyster Harbour.

Nouria polymorphinoides Heron-Allen and Earland

Nouria polymorphinoides Heron-Allen and Earland 1914, p. 376, Plate XXXVII, Figs. 1-15; Logan 1959, p. 204, 246.

Several specimens were obtained from one sample. This species was first described from the Kerimba Archipelago. Logan records it from Shark Bay, on the west coast of Western Australia. It is characteristic of shallow waters in the sub-tropical Indian Ocean but the Oyster Harbour record shows that its distribution extends to temperate latitudes.

Ammobaculites agglutinans (d'Orbigny)

Spirolina agglutinans d'Orbigny 1846, p. 137, Plate VII, Figs. 10-12.
Ammobaculites agglutinans (d'Orbigny); Chapman 1941, p. 191; Logan 1959, p. 181, 232.

The species has been recorded from Bass Strait and Shark Bay. The Oyster Harbour occurrence is intermediate in this extensive distribution along the southern Australian coastline.

Haplophragmoides sp. aff. **grandiformis** Cushman

Haplophragmoides grandiformis Cushman 1910, p. 440, text-fig. 11; Chapman and Parr 1935, p. 3; Chapman 1941, p. 190.

This distinctive species selects heavy mineral and quartz sand grains for its test, binding them with a yellowish-brown cement. The specimens from Oyster Harbour, however, do not attain the dimension of Cushman's type (3mm diameter). Distribution of the species extends from south-east Australia to Oyster Harbour.

Textularia candeiana d'Orbigny

Textularia candeiana d'Orbigny 1839, p. 143, Plate I, Figs. 25-27; Chapman and Parr 1935, p. 3; Heron-Allen and Earland 1915, p. 627.

All Australian records of this species, as far the author is aware, are from the southern coast of Western Australia.

Textularia conica d'Orbigny

Textularia conica d'Orbigny 1839, p. 143, Plate I, Figs. 19-20; Chapman 1941, p. 191; Parr in Fairbridge, 1950, p. 70; Parr 1945, p. 194.

This species has a wide distribution in southern Australian coastal waters.

Trochammina inflata (Montagu)

Nautilus inflatus Montagu 1808, p. 81, Plate XVIII, Fig. 3.
Trochammina inflata (Montagu); Parr 1945, p. 194.

A distinctive shallow water species, tolerant of the brackish conditions in the mouths of creeks and estuaries, also known to occur off Barwon Heads, Victoria.

Gaudryina (Pseudogaudryina) hastata (Parr)

Gaudryina hastata Parr 1932b, p. 219, Plate XXII, Fig. 40 a, b; Chapman and Parr 1935, p. 4.
Gaudryina (Pseudogaudryina) hastata (Parr); Parr in Fairbridge, 1950, p. 70.

The species is known to occur from the coast of New South Wales westwards to Point Peron, near Perth, Western Australia.

Gaudryina triangularis Cushman

Gaudryina triangularis Cushman 1911, p. 65, text-fig. 104 a-c; Chapman and Parr 1935, p. 4; Chapman 1941, p.193.

A large robust species with some variation in the arrangement of the later, inflated, uniserial chambers; distributed in southern Australian waters from Bass Strait to Oyster Harbour.

Gaudryina triangularis Cushman var. **angulata** Cushman

Gaudryina rugosa d'Orbigny; Heron-Allen and Earland 1915, p. 635.
Gaudryina triangularis Cushman var. *angulata* Cushman 1924, p. 22; Cushman 1932, p. 14, Plate III, Fig. 7 a, b.

The Oyster Harbour specimens follow precisely the descriptions quoted above and agree well with the published figures. This, as far as the author is aware, is the first Australian record for the species.

Clavulina difformis Brady

Clavulina angularis d'Orbigny var. *difformis* Brady 1884, p. 396, Plate XLVIII, Figs. 25-31.
Clavulina difformis Brady; Chapman and Parr 1935, p. 4.

This species differs from *Clavulina pacifica* Cushman in that it is polygonal or quadrangular in transverse section rather than triangular, and also in possessing a rougher test. It dominates over *C. pacifica* in Oyster Harbour and has also been recorded from the Great Australian Bight.

Clavulina pacifica Cushman

Clavulina pacifica Cushman 1924, p. 22 Plate VI, Figs. 7-11; Parr in Fairbridge, 1950, p. 70; Logan 1959, p. 183, 237.

This species is very rare in Oyster Harbour which may be a fringe location for it. It is recorded northwards along the west coast of Western Australia from Triggs Island, near Perth, from Geraldton and from Shark Bay. Only a few specimens are recorded from Triggs Island and Geraldton, but the species is frequent in Shark Bay.

Clavulina serventyi Chapman and Parr = *Pseudoclavulina serventyi* (Chapman and Parr); Barker 1960, p. 98.

Clavulina serventyi Chapman and Parr 1935, p. 5, Plate I, Fig. 7 a, b; Chapman 1941, p. 192; Parr 1950, p. 284.

Several samples from Oyster Harbour contain many examples of this species which was originally described from the Great Australian Bight. Parr has also recorded it off Tasmania.

Cribrobulimina polystoma (Parker and Jones)

Valvulina polystoma Parker and Jones 1865, p. 437, 438, table X.

Cribrobulimina polystoma (Parker and Jones); Chapman and Parr 1935, p. 4; Parr in Fairbridge, 1950, p. 70.

A distinctive, robust species, its known distribution in Australian waters extends from the coast near Melbourne, Victoria, westwards to Oyster Harbour, then north to Perth and Geraldton in Western Australia.

Nubecularia lucifuga Defrance

Nubecularia lucifuga Defrance 1825, p. 210; Brady 1884, p. 134, Plate I, Figs. 9-16; Chapman and Parr 1935, p. 3; Parr 1945, p. 195.

Brady's text and figures emphasise the variability of this species which is widely distributed in southern Australian waters. The Oyster Harbour specimens are highly variable in their morphology and some acquire the calcareous encrustation which is a further characteristic of this species.

Parrina bradyi (Millett)

Nubecularia inflata Brady 1884, p. 135, Plate I, Figs. 5-8.

Nubecularia bradyi Millett 1898, p. 261, Plate V, Fig. 6 a, b.

Parrina bradyi (Millett); Cushman 1932, p. 74, Plate XVII, Figs. 1-4; Chapman and Parr 1935, p. 3.

Consisting of an irregular series of inflated chambers, with a single aperture, or with numerous apertures, usually irregularly placed, this species is characteristic of shallow water environments in the Indo-Pacific.

Hauerina sp.

Only one specimen. The relationships of this species are to *H. diversa* Cushman and to *H. intermedia* Howchin. It resembles the former in size, shape, slight curvature of sutures, and ornamentation, and the latter in its aperture, which is non-cribrate and in its inflated chambers.

Spiropthalmidium concentricum (Terquem and Berthelin)

Spiroloculina concentrica Terquem and Berthelin 1875, p. 80, Plate VII, Figs. 1-4.

Spiropthalmidium concentricum (Terquem and Berthelin); Ellis and Messina 1940 et seq, volume 2.

Three specimens, one representing a costate variety of this species.

Vertebralina striata d'Orbigny

Vertebralina striata d'Orbigny 1826, p. 283; Brady 1884, p. 187, Plate XII, Figs. 14-16; Parr in Fairbridge, 1950, p. 71; Logan 1959, p. 203, 270.

This well-known species is widely distributed in the shallow water margins of warm latitude seas. Along the coast of Western Australia it is common in Oyster Harbour, and has been recorded from Garden Island, near Perth, from Geraldton, and throughout Shark Bay.

Vertebralina sp.

There are several examples. The species is similar to *V. striata* d'Orbigny in its initial cornuspirine coiling, ornamentation and aperture, but typically contains more chambers, is narrower and has cuspate margins. *V. striata* is known to be highly variable, however, so that this species may well represent one extreme of its development.

Spiroloculina

The classification of Loeblich and Tappan (1961) differs markedly from other, more familiar, classifications (Cushman 1950, Glaessner 1945) in that the Spiroloculininae are included as a sub-family of the family Nubeculariidae rather than in the family Miliolidae. The distinction rests on whether *Spiroloculina*, in its early stages, has a quinqueloculine or cornuspirine coiling. Loeblich and Tappan are followed here.

Spiroloculina angulata Cushman

Spiroloculina grata Terquem var. *angulata* Cushman 1917, p. 36, Plate VII, Fig. 5 a, b.

Spiroloculina angulata Cushman; Asano 1951, part 6, p. 12, Figs. 85, 86.

This species differs from *Spiroloculina antillarum* d'Orbigny in that it possesses a keeled periphery. It possibly has been recorded as *S. antillarum* by previous workers on Australian faunas.

Spiroloculina antillarum d'Orbigny

Spiroloculina antillarum d'Orbigny 1839, p. 166, Plate IX, Figs. 3, 4; Parr 1932*a*, p. 9; Parr 1945, p. 197; Parr in Fairbridge, 1950, p. 70; Logan 1959, p. 195, 263.

Recorded in southern Australian coastal waters from Victoria westwards to Oyster Harbour, then north to Geraldton and on to Shark Bay.

Spiroloculina canaliculata d'Orbigny = *Spiroloculina communis* Cushman and Todd; Barker 1960, p. 20.

Spiroloculina canaliculata d'Orbigny 1846, p. 269, Plate XVI, Figs. 10-12; Chapman and Parr 1935, p. 3; Chapman 1941, p 187.

This species was recorded by Brady (1884, p. 151, Plate X, Figs. 3, 4) as *Spiroloculina impressa* Terquem from shallow water in the tropical Pacific. The Australian records cited, however, are from temperate latitudes.

Spiroloculina hadai Thalmann

Spiroloculina hadai Thalmann 1933, p. 354, Asano 1951, part 6, p. 14, Figs. 97, 98.

Many specimens were identified in Oyster Harbour, apparently the first record of this species in southern Australian waters.

Spiroloculina milletti Wiesner = *Massilina milletti* (Wiesner); Barker 1960, p. 18.

Spiroloculina nitida d'Orbigny 1826, p. 298; Brady 1884, p. 149, Plate IX, Figs. 9, 10.

Spiroloculina milletti Wiesner; Chapman and Parr 1935, p. 3; Parr in Fairbridge, 1950, p. 70; Parr 1945, p. 197.

Common in the Indo-Pacific. The Australian records cited give a distribution from Barwon Heads, Victoria to Geraldton in Western Australia. It is possible that Logan (1959, p. 264) has called this species *Spiroloculina antillarum* d'Orbigny var. *aequa* Cushman, if so its distribution in Western Australia extends nearly to Carnarvon.

Planispirinoides bucculentus (Brady)

Miliolina bucculenta Brady 1884, p. 170, Plate CXIV, Fig. 3 a, b.
Planispirina bucculenta (Brady); Chapman and Parr 1935, p. 3; Chapman 1941, p. 186; Parr 1945, p. 195.
Planispirinoides bucculentus (Brady); Parr 1950, p. 287, text-figs. 1-5, Plate VI, Figs. 1-6.

The sections figured by Parr (1950) make it clear that this is a nubeculariid, although its external characters show affinities to the miliolids. Common in Oyster Harbour.

Pyrgo fornasinii Chapman and Parr

Biloculina ringens Brady 1884, p. 142, Plate II, Fig. 7.
Pyrgo fornasinii Chapman and Parr 1935, p. 5; Chapman 1941, p. 189.

A widely distributed species, but very rare in Oyster Harbour.

Triloculina cf. **flavescens** d'Orbigny

Triloculina flavescens d'Orbigny 1826, p. 300; Fornasinii 1905, p. 60, Plate I, Figs. 8, 8a, b.

Although this species has been recorded only rarely, and no Indo-Pacific records are known to the author, the Oyster Harbour specimen is so similar to the type figures that it is compared with d'Orbigny's species.

Triloculina laevigata d'Orbigny

Triloculina laevigata d'Orbigny 1826, p. 134; Asano 1951, part 6, p. 15, Figs. 103-105.

Some of the Oyster Harbour specimens included with this species are more round than the typical forms.

Triloculina rotunda d'Orbigny

Triloculina rotunda d'Orbigny 1825, p. 299, Heron-Allen and Earland 1915, p. 568, Plate XLII, Figs. 27-30; Logan 1959, p. 200, 268, Plate III, Fig. 7.

Rare in Oyster Harbour. Logan has recorded the species from Shark Bay.

Triloculina striatotrigonula (Parker and Jones)

Miliola (*Triloculina*) *striatotrigonula* Parker and Jones 1865, p. 438.
Triloculina striatotrigonula (Parker and Jones); Parr 1941, p. 305; Parr 1945, p. 198; Parr in Fairbridge, 1950, p. 70.

This species, which has also been recorded from Australian waters as *Triloculina insignis* (Brady), is common off the south coast of Australia and is known to occur as far north as Geraldton on the west coast of Western Australia.

Triloculina tricarinata d'Orbigny

Triloculina tricarinata d'Orbigny 1826, p. 299; Chapman and Parr 1935, p. 3; Chapman 1991, p. 188; Parr in Fairbridge, 1950, p. 70; Parr 1950, p. 294; Logan 1959, p. 200, 269.

Another widely distributed species, recorded in southern Australian waters from east of Tasmania to Shark Bay. The Oyster Harbour specimens are not as sharply-angled as the type figure.

Triloculina trigonula (Lamarck)

Miliola trigonula Lamarck 1804, p. 351, no. 3.
Triloculina trigonula (Lamarck); Chapman and Parr 1935, p. 3; Chapman 1941, p. 188; Parr 1945, p. 197; Parr in Fairbridge, 1950, p. 70; Parr 1950, p. 295; Logan 1959, p. 201, 269.

Common in southern Australian waters from Bass Strait to Shark Bay.

Triloculina sp. Cushman

Triloculina sp. Cushman 1932, p. 61, Plate XIII, Fig. 7 a-c.

This species, described by Cushman from the tropical Pacific, is probably close to *Triloculina laevigata* d'Orbigny. Cushman states that it seems to be on the borderline between *Triloculina* and *Quinqueloculina*. The few Oyster Harbour examples follow his figures.

Miliolinella circularis (Bornemann)

Triloculina circularis Bornemann 1885, p. 349, Plate XIX, Fig. 4; Chapman and Parr 1935, p. 3; Chapman 1941, p. 188; Parr 1945, p. 198; Logan 1959, p. 198, 267.
Miliolinella circularis (Bornemann); Asano 1951, part 6, p. 9, Figs. 65-67.

Common in southern Australian waters. The species described as *Miliolinella vigilax* Vella, from shallow waters in Cook Strait, New Zealand (Vella 1957, p. 21, Plate VII, Figs. 124-126), which closely resembles *M. circularis*, must be considered at least an ecotype of Bornemann's species.

Miliolinella labiosa (d'Orbigny)

Triloculina labiosa d'Orbigny 1839, p. 178, Plate X, Figs. 12-14; Parr 1932*b*, p. 220; Parr 1945, p. 198.

Placed in *Miliolinella* on the basis of its miliolinellid aperture. Parr consistently avoids the generic name *Miliolinella* and records this species as *Triloculina labiosa*, noting that it is widely distributed in the Indo-Pacific. Common in Oyster Harbour.

Miliolinella oblonga (Montagu)

Vermiculum oblongum Montagu 1803, p. 522, Plate XIV, Fig. 9.
Triloculina oblonga (Montagu); Parr 1932*a*, p. 10, Plate I, Fig. 15 a-c; Parr 1945, p. 198; Parr in Fairbridge, 1950, p. 70; Parr 1950, p. 294; Logan 1959, p. 199, 268.
Miliolinella oblonga (Montagu); Chapman 1941, p. 188.

Frequently recorded in Oyster Harbour this species occurs from Bass Strait to Shark Bay, in southern Australian waters.

Miliolinella sublineata (Brady)

Miliolina circularis (Bornemann) var. *sublineata* Brady 1884, p. 169, Plate IV, Fig. 7.
Triloculina circularis Bornemann var. *sublineata* (Brady); Parr 1945, p. 198; Logan 1959, p. 199, 268.
Miliolinella sublineata (Brady); Asano 1951, part 6, p. 10, Figs. 70-72.

The Oyster Harbour specimens resemble those described by Parr. Distribution of the species along the southern Australian coast extends from Barwon Heads, Victoria, to Shark Bay, Western Australia.

Sigmoilina australis (Parr) = *Miliolinella (?) australis* (Parr); Barker 1960, p. 10.

Quinqueloculina australis Parr 1932*a*, p. 7, Plate I, Figs. 8 a-c; Chapman and Parr 1935, p. 3; Chapman 1941, p. 186; Parr in Fairbridge, 1950, p. 70.
Sigmoilina australis (Parr); Parr 1945, p, 197; Parr 1950, p. 292.

A common Australian species. Logan (1959, p. 190) has placed it in *Miliolinella*, overlooking the fact that Vella has included *Sigmoilina* in the sub-family Miliolinellinae (Vella 1957, p. 20). The Oyster Harbour examples are small but typical.

Quinqueloculina bicornis (Walker and Jacob)

Serpula bicornis Walker and Jacob in Kanmacher, 1798, p. 633, Plate XIV, Fig. 2.
Quinqueloculina bicornis (Walker and Jacob); Heron-Allen and Earland 1915, p. 580.

Very rare in Oyster Harbour.

Quinqueloculina bosciana d'Orbigny

Quinqueloculina bosciana d'Orbigny 1839, p. 191, Plate XI, Figs. 22-24; Heron-Allen and Earland 1915, p. 566; Parr in Fairbridge, 1950, p. 70.

Frequently recorded in Oyster Harbour, this species shows some variation in the length and width of its test and in its ornamentation. It has also been recorded from Triggs Island, near Perth.

Quinqueloculina bradyana Cushman

Quinqueloculina bradyana Cushman 1917, p. 52, Plate XVIII, Fig. 2; Parr in Fairbridge, 1950, p. 70; Parr 1950, p. 290, Plate VI, Fig. 11; Logan 1959, p. 185, 252, Plate II, Fig. 5.

Distributed in southern Australian waters from Bass Strait to Shark Bay. Very rare in Oyster Harbour.

Quinqueloculina costata d'Orbigny

Quinqueloculina costata d'Orbigny 1826, p. 301; Parr 1932*a*, p. 8, Plate I, Fig. 9; Parr 1945, p. 197; Parr in Fairbridge, 1950, p. 70.

The distribution of this small species in southern Australian waters extends from Melbourne, Victoria, to Geraldton, Western Australia.

Quinqueloculina dilatata d'Orbigny

Quinqueloculina dilatata d'Orbigny 1839, p. 192, Plate XI, Figs. 28-30; Parr 1945, p. 196.

Rare in Oyster Harbour, this distinctive species also occurs off Barwon Heads, Victoria.

Quinqueloculina granulocostata Germeraad

Quinqueloculina granulocostata Germeraad 1946, p. 63; Logan 1959, p. 187, 252, Plate II, Fig. 6.

Examples of this large Indo-Pacific species, also known to occur in Shark Bay, were found in several samples from Oyster Harbour.

Quinqueloculina cf. **inaequalis** d'Orbigny

Quinqueloculina inaequalis d'Orbigny 1839, p. 142, Plate III, Figs. 28-30.

Two specimens. These tend to *Q. inaequalis* rather than *Q. sigmoilinoides* Vella in respect of their apertures and the concavo-convexity of their chambers. Vella's species (Vella 1957, p. 24, Plate VI, Figs. 115-117) should be renamed as *Q. sigmoilinoides* is already occupied (Gianotti 1953, p. 43, Plate IV, Fig. 1 a-d).

Quinqueloculina lamarckiana d'Orbigny

Quinqueloculina lamarckiana d'Orbigny 1839, p. 189, Plate XI, Figs. 14, 15; Chapman and Parr 1935, p. 3; Parr 1945, p. 196; Chapman 1941, p. 187; Parr in Fairbridge, 1950, p. 70.

This common species has been recorded in southern Australian waters from Bass Strait to Geraldton.

Quinqueloculina poeyana d'Orbigny

Quinqueloculina poeyana d'Orbigny 1839, p. 191, Plate XI, Figs. 25-27; Chapman and Parr 1935, p. 3; Parr 1950, p. 290.

Differentiated from *Q. costata* d'Orbigny by its larger test, dull finish, stronger ribbing and more prominent tooth, this species is also known to occur in the Great Australian Bight and off Albany.

Quinqueloculina polygona d'Orbigny

Quinqueloculina polygona d'Orbigny 1839, p. 198, Plate XII. Figs. 21-23; Chapman and Parr 1935, p. 3.

A few rather worn examples were identified. Chapman and Parr record the species from the western Great Australian Bight.

Quinqueloculina seminula (Linné)

Serpula seminulum Linné 1758, p. 1264, no. 791 (12th edition).

Quinqueloculina seminula (Linné); Chapman 1941, p. 187; Parr in Fairbridge, 1950, p. 70; Parr 1950, p. 289; Logan 1959, p. 188, 256.

This very common species has a complex taxonomic history, and has still to be described adequately. It has been recorded in southern Australian waters from Bass Strait to Perth. Logan (1959), describing the Shark Bay fauna, places a strongly-ribbed population in *Q. seminula,* but his material may well be *Q. seminula* var. *jugosa* Cushman. The Oyster Harbour specimens are all of the typical smooth-shelled variety.

Quinqueloculina seminula (Linné) var. **longa** Gherke

Quinqueloculina seminula (Linné) var. *longa* Gherke 1938, p. 306, Plate II, Figs. 5-8; Kruit 1955, p. 467, Plate I, Fig. 11.

Gherke's material was fossil but the species is known to occur to-day, for example in the Rhone delta (Kruit 1955), an environment somewhat similar to Oyster Harbour in respect of salinity, temperature and depth.

Quinqueloculina stelligera Schlumberger

Quinqueloculina stelligera Schlumberger 1893, p. 68, text-fig. 17, Plate II, Figs. 58, 59; Cushman 1929, p. 28, Plate III, Figs. 3, 4.

The few Oyster Harbour examples of this species are rather worn.

Quinqueloculina striata d'Orbigny

Quinqueloculina striata d'Orbigny 1826, p. 301; Heron-Allen and Earland 1915, p. 579, Plate XLIV, Figs. 13-17.

This is the first record of the species from Western Australian waters.

Quinqueloculina subarenaria Cushman

Quinqueloculina subarenaria Cushman 1917, p. 44, Plate X, Figs. 1, 2; Asano 1951, part 6, p. 7, Figs. 49-51.

The holotype was described from shallow water off Singapore. Asano, however, records this species from cooler waters in the Japan Sea. It is frequent in some samples in Oyster Harbour; the first record for the species in Western Australian waters.

Quinqueloculina suborbicularis d'Orbigny

Quinqueloculina suborbicularis d'Orbigny 1826, p. 302; Vella 1957, p. 23, Plate VI, Figs. 102-104.

Vella (p. 23) states with justification that specific names, such as *Q. seminula* and *Q. vulgaris* d'Orbigny, have been applied to a wide variety of shells, and should be restricted to forms approaching the original figures and descriptions. The author follows Vella in reviving *Q. suborbicularis* for forms that have probably been recorded as *Q. vulgaris* by earlier workers on southern Australian faunas. The species is common in Oyster Harbour.

Quinqueloculina subpolygona Parr

Quinqueloculina subpolygona Parr 1945, p. 196 Plate XII, Fig. 2; Parr in Fairbridge, 1950, p. 70; Parr 1950, p. 290; Logan 1959, p. 189, 255, Plate II, Fig. 11.

Typical examples of this southern Australian species were identified in several samples.

Quinqueloculina sulcata d'Orbigny

Quinqueloculina sulcata d'Orbigny 1826, p. 301; Logan 1959, p. 189, 256, Plate II, Fig. 9.

Frequent in Oyster Harbour, this species also occurs in Shark Bay.

Quinqueloculina sp. *1*

Only two specimens preclude the formal definition of a new species.

Test small, sub-rectangular, rather compressed; wall smooth, porcellanous; chambers quinqueloculine; sutures depressed, somewhat indistinct; aperture a long, narrow slit, hooked at one end, with a slight lip; tooth absent.

Quinqueloculina sp. *2*

One example. Test small, elongate, with a slightly sinuous periphery, compressed; wall smooth, porcellanous; chambers quinqueloculine; sutures indistinct, oblique, somewhat depressed; neck prominent; aperture narrow, elliptical; tooth absent.

Schlumbergerina alveoliniformis (Brady)

Miliolina alveoliniformis Brady 1879, p. 268; Brady 1884, p. 181, Plate VIII, Figs. 15-20.
Schlumbergerina alveoliniformis (Brady); Thalmann 1932, p. 297.

Two juveniles are placed in this species which usually inhabits shallow waters of tropical latitudes.

Cribrolinoides curta (Cushman)

Quinqueloculina disparilis d'Orbigny var. *curta* Cushman 1917, p. 49, Plate XIV, Fig. 2; Logan 1959, p. 186, 252.
Cribrolinoides curta (Cushman); Asano 1951, part 6, p. 9, Figs. 63, 64.

Also recorded from Shark Bay, this small, biscuit-coloured species is very rare in Oyster Harbour.

Ptychomiliola separans (Brady)

Miliolina separans Brady 1881, p. 45; Chapman and Parr 1935, p. 3, 4, Plate I, Fig. 3; Chapman 1941, p. 187; Parr 1950, p. 291.

Apparently restricted to Australian waters, this unusual species has been recorded off the east and south coasts of Australia from Torres Strait to the Bight. The present record extends its known distribution further westwards.

Pseudomassilina australis (Cushman)

Massilina australis Cushman 1932, p. 32, Plate VIII, Fig. 2 a, b.
Pseudomassilina australis (Cushman); Lacroix, 1938, p. 3.

The type locality is off Cook Island in the Pacific where this species occurs in shallow water. It is very rare in Oyster Harbour.

Siphonaperta ammophila (Parr)

Quinqueloculina ammophila Parr 1932*a*, p. 8, text-fig. 1E, Plate I, Fig. 10 a, b; Chapman and Parr 1935, p. 3.
Massilina ammophila (Parr); Parr 1950, p. 292, Plate VI, Fig. 16.
Siphonaperta ammophila (Parr); Vella 1957, p. 19.

The type locality for this is Westernport Bay, south-east of Melbourne, Victoria, and it has also been recorded off Tasmania and in the Great Australian Bight. The present record extends its known distribution westwards. The Oyster Harbour examples, however, are only rarely as compressed as Parr's figured specimens and may be related more closely to *Quinqueloculina agglutinans* d'Orbigny.

Massilina annectens Schlumberger

Massilina annectens Schlumberger 1893, p. 78, text-figs. 35-37, Plate III, Figs. 77-79.

One specimen, closely resembling Schlumberger's Fig. 78.

Massilina cf. **planispiroidea** Martinotti

Massilina planispiroidea Martinotti 1921, p. 314, text-figs. 129, 130, Plate IV, Figs. 1-3.

One example, which is compared with Martinotti's species from the shores of Tripoli.

Massilina secans (d'Orbigny)

Quinqueloculina secans d'Orbigny 1826, p. 303.
Massilina secans (d'Orbigny); Logan 1959, p. 191, 245.

Very rare in Oyster Harbour. Recorded by Logan from Shark Bay as a stenohaline marine species.

Massilina secans (d'Orbigny) var. **tenuistriata** Earland

Miliolina (*Massilina*) *secans* (d'Orbigny) var. *tenusstriata* Earland 1905, p. 198, Plate XI, Fig. 5.
Massilina secans (d'Orbigny) var. *tenuistriata* Earland; Heron-Allen and Earland 1915, p. 582, Plate XLIV, Figs. 28-31.

Several examples from Oyster Harbour, the first record of this variety in Western Australian waters.

Peneroplis pertusus (Forskål)

Nautilus pertusus Forskål 1775, p. 125.
Peneroplis pertusus (Forskål) Parr in Fairbridge, 1950, p. 71; Logan 1959, p. 210.

This species, which has also been recorded from Shark Bay and Geraldton Harbour, is common in Oyster Harbour. It is usually smaller than *Peneroplis planatus* (Fichtel and Moll), and is further distinguished from that species by its fatter test and different aperture.

Peneroplis planatus (Fichtel and Moll)

Nautilus planatus Fichtel and Moll 1798, p. 91 (in an 1803 reprint).
Peneroplis planatus (Fichtel and Moll); Chapman and Parr 1935, p. 3; Parr 1945, p. 199; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 299; Logan 1959, p. 211, 246, Plate IV, Figs. 6, 7.

This widely distributed species is common in southern Australian waters from Victoria to Shark Bay. The Oyster Harbour specimens include forms tending towards *Spirolina arietina* (Batsch.)

Peneroplis sp.

Test large, initially close-coiled and thickened, becoming expanded towards the apertural end; ornamentation of numerous striae; aperture a row of pores along the median line of the apertural face. This species appears to be intermediate between *Peneroplis proteus* d'Orbigny, and *P. planatus,* differing from the former in its ornamentation, and from the latter in the general shape of its test and in the initial thickening. Several specimens were taken in Oyster Harbour.

Dendritina antillarum d'Orbigny

Dendritina antillarum d'Orbigny 1826, p. 285; Cushman 1930, part 7, p. 42, Plate XIV, Figs. 2, 3.

A few specimens with the characteristic dendritine aperture were identified as belonging to this species.

Spirolina cylindracea (Lamarck)

Spirolinites cylindracea Lamarck 1804, p. 245.
Spirolina cylindracea (Lamarck); Chapman and Parr 1935, p. 2.

This slender, cylindrical species has previously been recorded in Western Australian waters only from the western Great Australian Bight. It is rare in Oyster Harbour.

Marginopora vertebralis Quoy and Gaimard

Marginopora vertebralis Quoy and Gaimard in Blainville, 1830, p. 377; Chapman and Parr 1935, p. 3; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 299; Logan 1959, p. 215, 244.

Frequently recorded along the western coastline of Western Australia but rare along the southern coast of this State. Two broken specimens were found near the southern entrance to Oyster Harbour.

Guttulina (Sigmoidina) pacifica (Cushman and Ozawa)

Sigmoidella (Sigmoidina) pacifica Cushman and Ozawa 1928, p. 19, Plate II, Fig. 13.
Guttulina (Sigmoidina) pacifica (Cushman and Ozawa); Asano 1951, part 8, p. 5, Figs. 24-26.

Only one example of this common Indo-Pacific species.

Guttulina kishinouyi Cushman and Ozawa

Guttulina kishinouyi Cushman and Ozawa 1930, p. 40, Plate VIII, Figs. 5, 6; Asano 1951, part 8, p. 2, Figs. 6, 7.

Not previously recorded from Western Australian waters, and very rare in Oyster Harbour.

Guttulina cf. **lactea** (Walker and Jacob)

Serpula lactea Walker and Jacob in Kanmacher, 1798, p. 634. Plate XIV, Fig. 4.
Guttulina lactea (Walker and Jacob); Parr and Collins 1937, p. 195, Plate XII, Fig. 8; Chapman 1941, p. 164; Parr 1945, p. 204.

The single specimen is hesitantly compared with this species which it appears to resemble most nearly, and which has been previously recorded from south-eastern Australia and Barwon Heads, Victoria.

Guttulina yabei Cushman and Ozawa

Guttulina yabei Cushman and Ozawa 1929, p. 68, Plate XIII, Fig. 2, Plate XIV, Fig. 6 a, b; Parr and Collins 1937, p. 192, Plate XIII, Fig. 4 a-c; Chapman 1941, p. 164; Parr 1945, p. 204.

Recorded in south-eastern Australian waters from Sydney to Barwon Heads, Victoria. The slender form figured by Parr and Collins was present in three samples from Oyster Harbour where it occurs more frequently than any other polymorphinid.

Guttulina yamazakii Cushman and Ozawa

Guttulina yamazakii Cushman and Ozawa 1930, p. 40, Plate VIII, Figs. 3, 4; Parr and Collins 1937, p. 196, Plate XIII, Fig. 5 a-c; Logan 1959, p. 205, 244, Plate III, Fig. 8.

One typical example of this species was identified in Oyster Harbour. Logan has microradiographed a specimen from Shark Bay.

Sigmoidella elegantissima (Parker and Jones)

Polymorphina elegantissima Parker and Jones 1864, p. 438.
Sigmoidella elegantissima (Parker and Jones); Chapman and Parr 1935, p. 2; Parr and Collins 1937, p. 206, Plate XIV, Fig. 9; Parr 1945, p. 205; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 335.

Recorded in southern Australian waters from Port Jackson, N.S.W., to Geraldton, W.A. Very rare in Oyster Harbour.

Oolina globosa (Montagu)

Vermiculum globosum Montagu 1803, p. 523.
Lagena globosa (Montagu); Brady 1884, p. 452, text-fig. 11 a-m, Plate LVI, Figs. 1-3; Chapman and Parr 1935, p. 2.
Entosolenia globosa (Montagu); Parr 1945, p. 204.
Oolina globosa (Montagu); Parr 1950, p. 302.

Only one example of this small species.

Bolivinella folium (Parker and Jones)

Textularia agglutinans d'Orbigny var. *folium* Parker and Jones 1865, p. 370, 420, Plate XVIII, Fig. 19.
Bolivinella folium (Parker and Jones); Chapman and Parr 1935, p. 2; Chapman 1941, p. 169; Parr 1945, p. 205; Parr in Fairbridge, 1950, p. 71; Logan 1959, p. 216, 235.

The type locality for this species is a shore sand near Melbourne, Victoria. It is common in Australian waters as the records cited indicate.

Bolivina earlandi Parr

Bolivina punctata d'Orbigny 1839, p. 63, Plate VIII, Figs. 10-12; Chapman 1941, p. 167.
Bolivina earlandi Parr; Parr 1950, p. 339, Plate XII, Fig. 16 a, b.

Widely distributed in Australian waters. The Oyster Harbour specimens follow Parr's species in possessing rounded, rather than sharp-edged, margins.

Reussella ensiformis (Chapman)

Verneuilina ensiformis Chapman 1910, p. 271, Plate II, Fig. 1 a, b.
Reussia ensiformis (Chapman); Chapman and Parr 1935, p. 2, 4, Plate I, Fig. 1.

Several examples of this species were found thus reinforcing Chapman and Parr's record of one specimen from the Great Australian Bight. This is important, as prior to Chapman and Parr's paper all records of the species were from the Oligocene and Miocene of Victoria. The generic name *Reussella* is used after Galloway (1933, fide Ellis and Messina 1940 *et seq.*).

Siphogenerina raphana (Parker and Jones)

Uvigerina (Sagrina) raphanus Parker and Jones 1865, p. 364, Plate XVIII, Figs. 16 a, b, 17.
Siphogenerina raphanus (Parker and Jones); Chapman and Parr 1935, p. 2; Parr 1945, p. 207; Parr in Fairbridge, 1950, p. 71; Logan 1959, p. 220, 260.

Widely distributed in southern Australian waters from Barwon Heads to Shark Bay.

Discopulvinulina australis (Parr) = *Discorbis australis* Parr; Barker 1960, p. 180.

Discorbis australis Parr 1932b, p. 227, Plate XXII, Fig. 31 a-c; Chapman and Parr 1935, p. 3; Chapman 1941, p. 171; Parr 1945, p. 209; Parr in Fairbridge, 1950, p. 71; Logan 1959, p. 221, 238.
Discopulvinulina australis (Parr); Asano 1951, part 14, p. 3, Figs. 20-22.

Distributed widely in southern Australian waters from Bass Strait to Shark Bay. Several small specimens were recorded at Oyster Harbour.

Discopulvinulina bradyi (Cushman) = *Rosalina bradyi* (Cushman); Barker 1960, p. 178.

Discorbis globularis d'Orbigny var. *bradyi* Cushman 1915, p. 12, Plate VIII, Fig. 1.
Discopulvinulina bradyi (Cushman); Asano 1951, part 14, p. 4, Figs. 25, 26.

One example of this widely distributed species common in the shallow waters of sub-tropical and temperate seas.

Discorbis cf. **advena** Cushman = *Conorboides* cf. *advena* (Cushman); Barker 1960, p. 180.

Discorbina rosacea (d'Orbigny); Brady 1884, in part, p. 644, Plate LXXXVII, Fig. 1.
Discorbis advena Cushman 1922, p. 40.

Cushman established this species from one of Brady's specimens figured as *Discorbina rosacea*. Brady states that *D. rosacea* is common in almost every sea, but Cushman's separated species is usually recorded from warm shallow waters in the western Atlantic. The Oyster Harbour example, though small, agrees well with Brady's figure and Cushman's description.

Discorbis australensis Heron-Allen and Earland = *Pileolina (?) australensis* (Heron-Allen and Earland); Barker 1960, p. 184.

Discorbina pileolus Brady 1884, p. 649, Plate LXXXIX, Figs. 2-4.

Discorbis australensis Heron-Allen and Earland 1932, p. 416; Parr 1945, p. 209.

Several examples including a twinned specimen. Parr, in recording the species from Barwon Heads, says it is common on the east coast of Australia.

Discorbis dimidiatus (Jones and Parker) = *Discorbis* sp. nov.; Barker 1960, p. 180.

Discorbina dimidiata Jones and Parker in Carpenter, 1862, p. 201, text-fig. 32B.

Discorbis dimidiatus (Jones and Parker); Chapman and Parr 1935, p. 3; Chapman 1941, p. 172; Parr 1945, p. 208; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 353.

The commonest species of *Discorbis* in southern Australian waters, known to occur from below Sydney westwards to Oyster Harbour and then northwards as far as North-West Cape. Among the many examples from Oyster Harbour were several large ones, thus supporting Parr's opinion that the largest specimens are usually found in temperate coastal waters.

Discorbis dimidiatus (Jones and Parker) var. **acervulinoides** Parr

Discorbis vesicularis (Lamarck) var. *acervulinoides* Parr 1932*b*, p. 229, Plate XXI, Fig. 30 a-c.

Discorbis dimidiatus (Jones and Parker) var *acervulinoides* Parr; Chapman and Parr 1935, p. 3; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 353.

Distinguished by its conical test this variety was described from the coast of South Australia. It is known to occur in Western Australian waters from the Bight to as far north as Geraldton.

Discorbis mira Cushman = *Discorbina (?) mira* (Cushman); Barker 1960, p. 180.

Discorbis mira Cushman 1922, p. 39, Plate VI, Figs. 10-11; Chapman and Parr 1935, p. 3; Parr in Fairbridge, 1950, p. 71.

Recorded in Western Australian waters from the Bight to near Perth.

Discorbis opercularis (d'Orbigny) = *Pileolina (?) opercularis* (d'Orbigny); Barker 1960, p. 184.

Rosalina opercularis d'Orbigny 1839, p. 93, Plate III, Figs. 24, 25, Plate IV, Fig. 1.

Discorbis opercularis (d'Orbigny); Chapman and Parr 1935, p. 3; Chapman 1941, p. 172; Parr 1945, p. 209; Parr 1950, p. 355.

This distinctive species though never common is widely distributed in Australian waters although it has yet to be recorded from the west coast of Western Australia.

Discorbis patelliformis (Brady) = *Pileolina (?) patelliformis* (Brady); Barker 1960, p. 182.

Discorbina patelliformis Brady 1884, p. 647, Plate LXXXVIII, Fig. 3 a-c, Plate LXXXIX, Fig. 1 a-c.

Discorbis patelliformis (Brady); Chapman and Parr 1935, p. 3; Parr 1945, p. 209; Logan 1959, p. 222, 239, Plate V, Fig. 9.

Brady describes this as a shallow water Indo-Pacific species. It is well-known from the southern coast of Australia. The Oyster Harbour specimens are all small.

Eponides praecinctus (Karrer) = *Cibicides praecinctus* (Karrer); Barker, 1960, p. 196.

Rotalia praecincta Karrer 1868, p. 189, Plate V, Fig. 7.

Truncatulina praecincta (Karrer); Brady 1884, p. 667, Plate XCV, Figs. 1-3.

Eponides praecinctus (Karrer); Asano 1951, part 14, p. 11, Figs. 80-82.

Common on the Pacific coast of Japan and in the tropical southern Pacific. Brady also records it from the Red Sea. It is rare in Oyster Harbour.

Eponides repandus (Fichtel and Moll)

Nautilus repandus Fichtel and Moll 1798, p. 35, Plate III, Figs. a-d, in an 1803 reprint.

Eponides repandus (Fichtel and Moll); Chapman and Parr 1935, p. 3; Chapman 1941, p. 173; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 360.

Common off the southern coast of Australia from Bass Strait to Albany. Barker (1960, p. 214) comments on the taxonomy of this species.

Discorbinella biconcava (Jones and Parker)

Discorbina biconcava Jones and Parker in Carpenter, 1862, p. 201, text-fig. 32G.

Planulina biconcava (Jones and Parker); Chapman and Parr 1935, p. 3; Chapman 1941, p. 176.

Discorbinella biconcava (Jones and Parker); Parr 1945, p. 211.

The type locality for this species is near Melbourne, Victoria. It is known to occur also in the Gulf of Carpentaria, Torres Strait, Port Jackson, Bass Strait, off Cape Wiles and in the Bight. There are two small specimens from Oyster Harbour.

Planorbulina acervalis Brady

Planorbulina acervalis Brady 1884, p. 657, Plate XCII, Fig. 4; Parr in Fairbridge, 1950, p. 72; Logan 1959, p. 231, 247.

Very rare in Oyster Harbour, this species has also been recorded from Perth, Geraldton and Shark Bay in Western Australian waters. It is differentiated from *Planorbulina mediterranensis* d'Orbigny by its numerous acervuline segments.

Planorbulina rubra d'Orbigny

Planorbulina rubra d'Orbigny 1826, p. 280; Parr 1932*b*, p. 232, Plate XXII, Fig. 51 a-c; Parr in Fairbridge, 1950, p. 72; Parr 1950, p. 368.

A few examples of this species, recorded by Parr from shallow water off the coasts of Victoria and South Australia, and off Albany, were found in Oyster Harbour. All possess the characteristic reddish tinge. The type locality is a shore sand from Fremantle, Western Australia, and the species is also known from Geraldton Harbour.

Planorbulinella larvata (Parker and Jones)

Planorbulina larvata Parker and Jones 1865, p. 379, 380, Plate XIX, Fig. 3 a, b; Heron-Allen and Earland 1915, p. 706.

Planorbulinella larvata (Parker and Jones); Thalmann 1932, p. 309.

One typical example.

Acervulina inhaerens Schultze

Acervulina inhaerens Schultze 1854, p. 68, Plate VI, Fig. 12; Parr 1945, p. 214; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 368.

Several specimens. The species is widely distributed along the southern coastline of Australia, and occurs as far north as Geraldton in Western Australia.

Streblus beccarii (Linné)

Nautilus beccarii Linné 1758, p. 710, Plate I, Fig. 1 a-c.

Rotalia beccarii (Linné); Chapman and Parr 1935, p. 3; Logan 1959, p. 225, 259.

Streblus beccarii (Linné); Chapman 1941, p. 173; Parr 1945, p. 213; Parr in Fairbridge, 1950, p. 72.

This highly variable species is recorded spasmodically throughout Oyster Harbour. Its distribution extends from Bass Strait to Shark Bay.

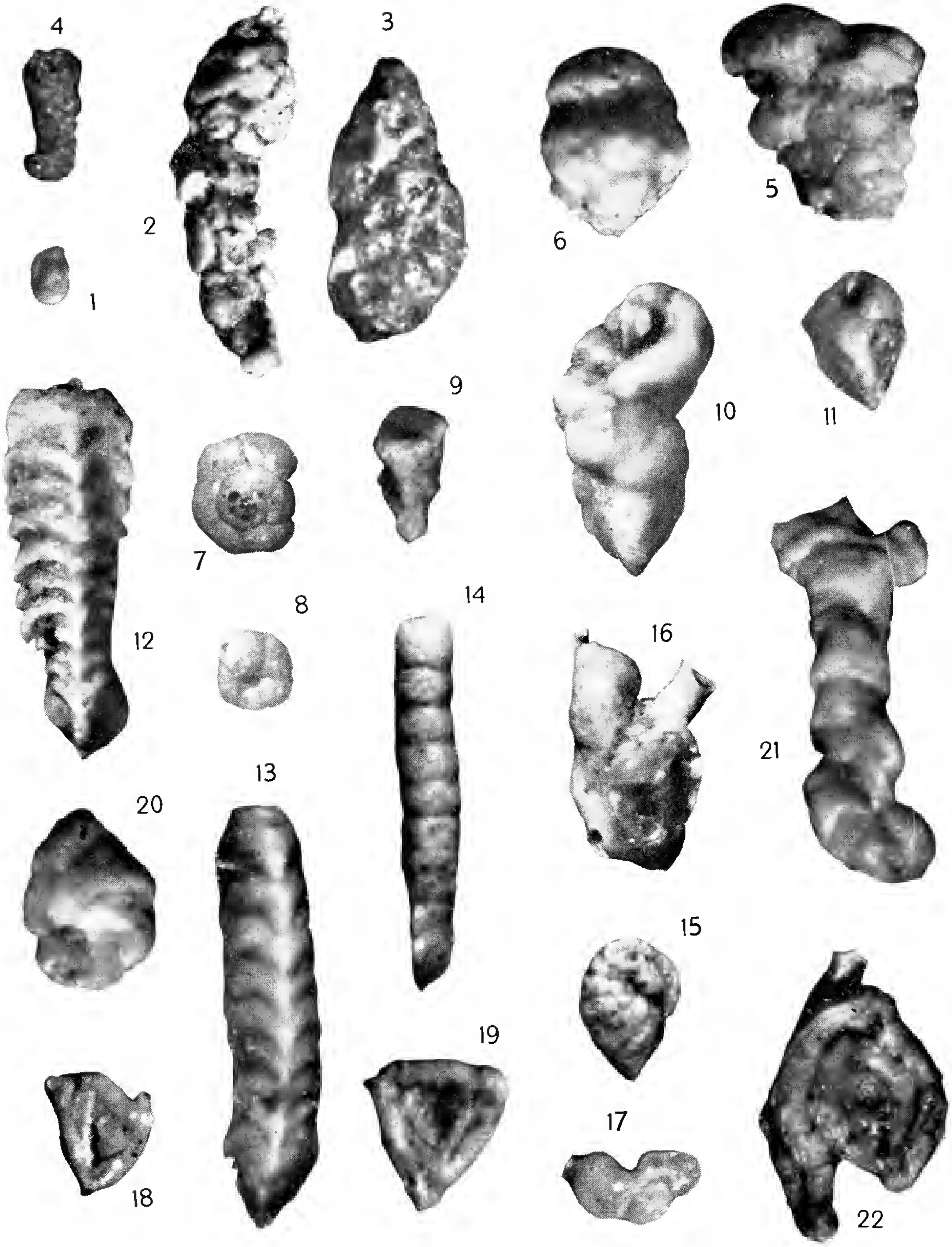

PLATE I

Rotalia trispinosa Thalmann = *Asterorotalia trispinosa* (Thalmann); Barker 1960, p. 238.

Rotalia pulchella Brady 1884, p. 710, Plate CXV, Fig. 8 a, b.
Rotalia trispinosa Thalmann 1933, p. 248; Asano 1951, part 14, p. 17, Fig. 127.

A characteristic Indo-Pacific species, but very rare in Oyster Harbour. It has also been recorded in Cockburn Sound, near Perth, Western Australia (R. A. McTavish personal communication).

Elphidium advenum (Cushman)

Polystomella advena Cushman 1922, p. 56, Plate IX, Figs. 11, 12.
Elphidium advenum (Cushman); Chapman 1941, p. 182; Parr 1945, p. 216; Parr in Fairbridge, 1950, p. 72; Logan 1959, p. 206, 241, Plate III, Fig. 16, Plate IV, Fig. 1.

Common in Australian waters, it occurs throughout Oyster Harbour, where it is the most abundant species.

Elphidium craticulatum (Fichtel and Moll)

Nautilus craticulatus Fichtel and Moll 1798, p. 51, Plate V, Figs. h-k, in an 1803 reprint.
Elphidium craticulatum (Fichtel and Moll); Chapman and Parr 1935, p. 2; Parr in Fairbridge, 1950, p. 72; Parr 1950, p. 373; Logan 1959, pp. 207, 241, Plate III, Figs. 14, 15.

The Australian records cited are all from Western Australian waters.

Elphidium crispum (Linné)

Nautilus crispus Linné 1758, p. 709, Plate I, Figs. 2 d-f (10th edition).
Elphidium crispum (Linné); Chapman and Parr 1935, p. 2; Chapman 1941, p. 182; Parr in Fairbridge, 1950, p. 72; Logan 1959, pp. 208, 242, Plate IV, Figs. 2, 3.

Common in southern Australian waters. This species apparently cannot tolerate the brackish conditions in the northern part of Oyster Harbour.

Elphidium incertum (Williamson)

Polystomella umbilicatula (Walker) var. *incerta* Williamson 1858, p. 44, Plate III, Fig. 82a.
Elphidium incertum (Williamson); Parr in Fairbridge, 1950, p. 72; Parr 1950, p. 373.

Previously recorded off Albany, this species is common in Oyster Harbour.

Elphidium jenseni (Cushman)

Polystomella jenseni Cushman 1924, p. 49, Plate XVI, Fig. 6.
Elphidium jenseni (Cushman); Chapman 1941, p. 182; Parr 1950, p. 372.

Known to occur off the coast of New South Wales, in Bass Strait and off Tasmania. Differentiated by its finely papillate umbilical area from *Elphidium macellum* (Fichtel and Moll), in which this feature is not present.

Elphidium laminatum (Terquem)

Polystomella laminata Terquem 1878, p. 16, Plate I, Fig. 8 a, b.

Rarely recorded, this species can be taken for an *Operculina* but the retral processes are quite distinct. It is characteristically highly compressed. Present near the southern entrance to Oyster Harbour.

Elphidium macellum (Fichtel and Moll)

Nautilus macellus Fichtel and Moll 1798, pp. 66, 68, Plate X, Figs. e-k, in an 1803 reprint.
Elphidium macellum (Fichtel and Moll); Chapman 1941, p. 183; Parr 1945, p. 216; Parr in Fairbridge, 1950, p. 72; Parr 1950, p. 372.

Common in southern Australian waters from Bass Strait to Perth.

Ozawaia tongaensis Cushman

Ozawaia tongaensis Cushman 1922, p. 80, Plate X, Figs. 7-10.

This Pacific species is very rare in Oyster Harbour.

Elphidiononion sp. aff. **simplex** (Cushman)

Elphidium simplex Cushman 1933, p. 52, Plate XII, Figs. 8, 9; Logan 1959, pp. 208, 243, Plate IV, Fig. 5.
Elphidium sp. aff. *simplex* Cushman; Parr 1945, p. 216, Plate XI, Fig. 8.

Parr describes a form, from Barwon Heads, Victoria, in which the retral processes are more prominent than in Cushman's species. The Oyster Harbour specimens resemble Parr's in this respect. The author follows Vella (1957, p. 38) in the use of the generic name *Elphidiononion*.

Globorotalia scitula (Brady)

Pulvinulina scitula Brady 1882, p. 716.
Globorotalia scitula (Brady); Chapman 1941, p. 181; Parr 1950, p. 367.

One example of this widely distributed pelagic species.

Globigerina bulloides d'Orbigny

Globigerina bulloides d'Orbigny 1826, p. 277; Chapman and Parr 1935, p. 3; Chapman 1941, p. 179; Parr 1945, p. 215; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 365.

There were several specimens from Oyster Harbour of this universally distributed pelagic species.

Orbulina universa d'Orbigny

Orbulina universa d'Orbigny 1839, p. 3, Plate I, Fig. 1; Chapman and Parr 1935, p. 3; Chapman 1941, p. 180; Parr 1945, p. 215; Parr 1950, p. 366.

Another pelagic species with world-wide distribution. One small example was found in Oyster Harbour.

Discanomalina sp.

This resembles *Anomalina colligera* Chapman and Parr, known from Bass Strait to the Bight (Chapman and Parr 1935, Chapman 1941, Parr 1950). The large area of clear shell material in the umbilical region of the ventral side, however, places it in *Discanomalina*.

PLATE I*

1: *Miliammina fusca* (Brady) x 20; 2: *Reophax scorpiurus* Montfort x 30; 3: *Nouria polymorphinoides* Heron-Allen and Earland x 30; 4: *Ammobaculites agglutinans* (d'Orbigny) x 20; 5: *Textularia candeiana* d'Orbigny x 30; 6: *T. conica* d'Orbigny x 30. Apertural view 7: *Trochammina inflata* (Montagu) x 30. Dorsal view; 8: *T. inflata* x 30. Ventral view; 9: *Gaudryina (Pseudogaudryina) hastata* (Parr) x 30; 10: *G. triangularis* Cushman x 30; 11: *G. triangularis* Cushman var. *angulata* Cushman x 30; 12: *Clavulina difformis* Brady x 30; 13: *C. pacifica* Cushman x 30; 14: *C. serventyi* Chapman and Parr x 30; 15: *Cribrobulimina polystoma* (Parker and Jones) x 20; 16: *Nubecularia lucifuga* Defrance x 30; 17: *Parrina bradyi* (Millett) x 30; 18: *Spiropthalmidium concentricum* (Terquem and Berthelin) x 30; 19: *S. concentricum* x 30. Costate variety; 20: *Vertebralina striata* d'Orbigny x 30; 21: *V.* sp. x 30; 22: *Ptychomiliola separans* (Brady) x 30.

* All photographs taken by the author using a Leica Reprovit II and microfilm, developed and printed by K. Bauer.

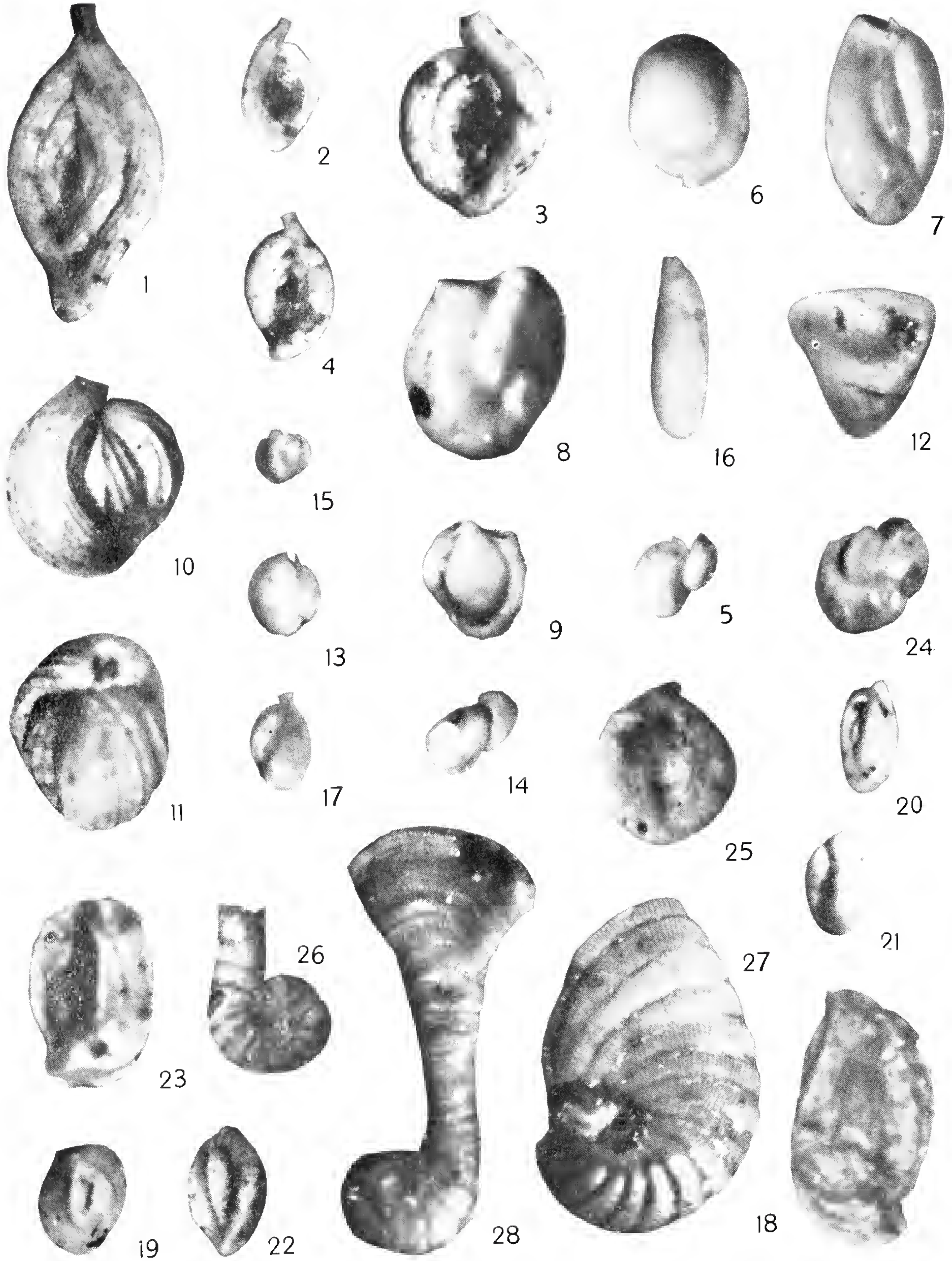

PLATE II

1: *Spiroloculina antillarum* d'Orbigny x 30; 2: *S. canaliculata* d'Orbigny x 30; 3: *S. hadai* Thalmann x 30; 4: *S. milletti* Wiesner x 30; 5: *Planispirinoides bucculentus* (Brady) x 30; 6: *Pyrgo fornasinii* Chapman and Parr x 30; 7: *Triloculina laevigata* d'Orbigny x 30; 8 and 9: *T. rotunda* d'Orbigny x 30. Both sides; 10 and 11: *T. striatotrigonula* (Parker and Jones) x 30. 11 is an apertural view; 12: *T. trigonula* (Lamarck) x 20. Apertural view; 13: *Miliolinella circularis* (Bornemann) x 20; 14: *M. labiosa* (d'Orbigny) x 30; 15: *Sigmoilina australis* (Parr) x 20; 16: *Quinqueloculina bosciana* d'Orbigny x 30; 17: *Q. costata* d'Orbigny x 30; 18: *Q. granulocostata* Germeraad x 20; 19: *Q. lamarckiana* d'Orbigny x 30; 20 and 21: *Q. seminula* (Linne) var. *longa* Gherke x 30. Both sides; 22: *Q. subarenaria* Cushman x 30: 23: *Q. subpolygona* Parr x 30; 24: *Pseudomassilina australis* (Cushman) x 30; 25: *Massilina secans* (d'Orbigny) var. *tenuistriata* Earland x 30; 26: *Spirolina cylindracea* (Lamarck) x 30. Broken specimen; 27: *Peneroplis planatus* (Fichtel and Moll) x 30; 28: *P.* sp. x 30.

Anomalina glabrata Cushman

Anomalina glabrata Cushman 1924, p. 39, Plate XII, Figs. 5-7: Chapman and Parr 1935, p. 3; Chapman 1941, p. 175.

One very small example of this species, which has also been recorded from Bass Strait and the Bight.

Cymbalopora poeyi (d'Orbigny) = *Cymbaloporetta squammosa* (d'Orbigny); Barker 1960, p. 210.

Rosalina poeyi d'Orbigny 1839, p. 100, Plate III, Figs. 18-20.
Cymbalopora poeyi (d'Orbigny); Brady 1884, p. 637, Plate CII, Fig. 13.

One small example of this widely distributed shallow water species.

Cymbaloporetta bradyi Cushman

Cymbalopora poeyi var. Brady 1884, p. 637, Plate CII, Fig. 14 a-d.
Cymbaloporetta bradyi Cushman 1931, p. 75; Logan 1959, pp. 228, 238.

One typical example of this species, which is also recorded by Logan from Shark Bay.

Tretomphalus bulloides (d'Orbigny) = *Tretomphalus planus* Cushman; Barker 1960, p. 210.

Rosalina bulloides d'Orbigny 1839, p. 98, Plate III, Figs. 2-5.
Cymbalopora (Tretomphalus) bulloides (d'Orbigny); Brady 1884, p. 638, Plate CII, Figs. 7-12.
Tretomphalus cf. *bulloides* (d'Orbigny); Logan 1959, p. 228.

In the majority of the Oyster Harbour examples the characteristic, final balloon-like chamber has been ruptured. Two specimens, however, retain it, enabling the ruptured individuals to be associated with the species by a comparison of their earlier rotaliform stages, which in all but one of the specimens have a reddish-brown colour. The exception is white.

Parr (1945, p. 212, Plate XI, Figs. 4, 5) has figured as *Tretomphalus concinnus* (Brady) from Barwon Heads, Victoria, forms similar to those which this author has assigned to *T. bulloides* after a study of d'Orbigny's and Brady's descriptions and figures. Logan has recorded from Shark Bay a *Tretomphalus* which he compares with *T. bulloides*.

Carpenteria sp.

Two juvenile specimens referable to this genus.

Virgulina cf. **schreibersiana** Czjzek

Virgulina schreibersiana Czjzek 1848, p. 147, Plate XIII, Figs. 18-21; Parr 1945, p. 205; Parr in Fairbridge, 1950, p. 71.

One specimen. This record has an added significance because Oyster Harbour is intermediate between Barwon Heads, Victoria, and Geraldton Harbour, Western Australia, where the species is already known to occur.

Nonion depressulum (Walker and Jacob)

Nautilus depressulus Walker and Jacob in Kanmacher, 1798, p. 641, Plate XIV, Fig. 33.
Nonion depressulum (Walker and Jacob); Chapman 1941, p. 181; Parr 1945, p. 215.

Several specimens, thus extending the known distribution of this species into Western Australian waters.

Cibicides lobatulus (Walker and Jacob)

Nautilus lobatulus Walker and Jacob in Kanmacher, 1798, p. 642, Plate XIV, Fig. 36.
Cibicides lobatulus (Walker and Jacob); Chapman and Parr 1935, p. 3; Chapman 1941, p. 176; Parr 1945, p. 214; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 364; Logan 1959, p. 230.

Frequently encountered in Oyster Harbour this species is widely distributed in southern Australian waters from Bass Strait to Shark Bay.

Cibicides pseudoungerianus (Cushman)

Truncatulina pseudoungerianus Cushman 1922, p. 97, Plate XX, Fig. 9.
Cibicides pseudoungerianus (Cushman); Chapman 1941, p. 176; Parr 1950, p. 365.

Common in southern seas. On the southern coastline of Australia it has been recorded off Tasmania and near Albany.

Cibicides refulgens (Montfort)

Nautilus (Rotalia) refulgens Montfort 1808, p. 122.
Cibicides refulgens (Montfort); Chapman and Parr 1935, p. 3; Chapman 1941, p. 177; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 363; Logan 1959, pp. 230, 236.

This universally distributed species is common in Oyster Harbour.

Cibicides tenuimargo (Brady)

Truncatulina tenuimargo Brady 1884, p. 662, Plate XCIII, Figs. 2, 3; Heron-Allen and Earland 1915, p. 707.

Four of Brady's localities are in eastern Australian waters. Oyster Harbour is intermediate between his records and those of Heron-Allen and Earland from the Kerimba Archipelago, making this occurrence of particular interest.

Dyocibicides biserialis Cushman and Valentine

Dyocibicides biserialis Cushman and Valentine 1930, p. 31, Plate X, Figs. 1, 2; Chapman 1941, p. 177.

Distinguished by the limbate, slightly raised sutures on its flattened face. Chapman has recorded it off south-eastern Australia.

Dyocibicides cf. **perforata** Cushman and Valentine

Dyocibicides perforata Cushman and Valentine 1930, p. 31, Plate X, Fig. 3 a-c; Asano 1951, part 13, p. 19, Fig. 50.

Sutures initially limbate and flush, but later non-limbate and slightly depressed. One example.

Spirillina inaequalis Brady

Spirillina inaequalis Brady 1879, p. 278, Plate VIII, Fig. 25 a, b; Chapman and Parr 1935, p. 2; Chapman 1941, p. 157; Parr 1945, p. 199; Parr in Fairbridge, 1950, p. 71; Parr 1950, p. 350.

Only one example of this well-known Indo-Pacific species, recorded in southern Australian waters from Bass Strait to Geraldton Harbour, was found in Oyster Harbour.

This completes the notes on the species. Specimens are stored at the Geology Department, in the University of Western Australia.

Conclusions

The value of foraminifera in environmental studies has been conveyed to some extent in the preceding discussions on the species. It must be realised, however, that they comprise only a single element in the complex biotope of the Harbour, and the ecological information they

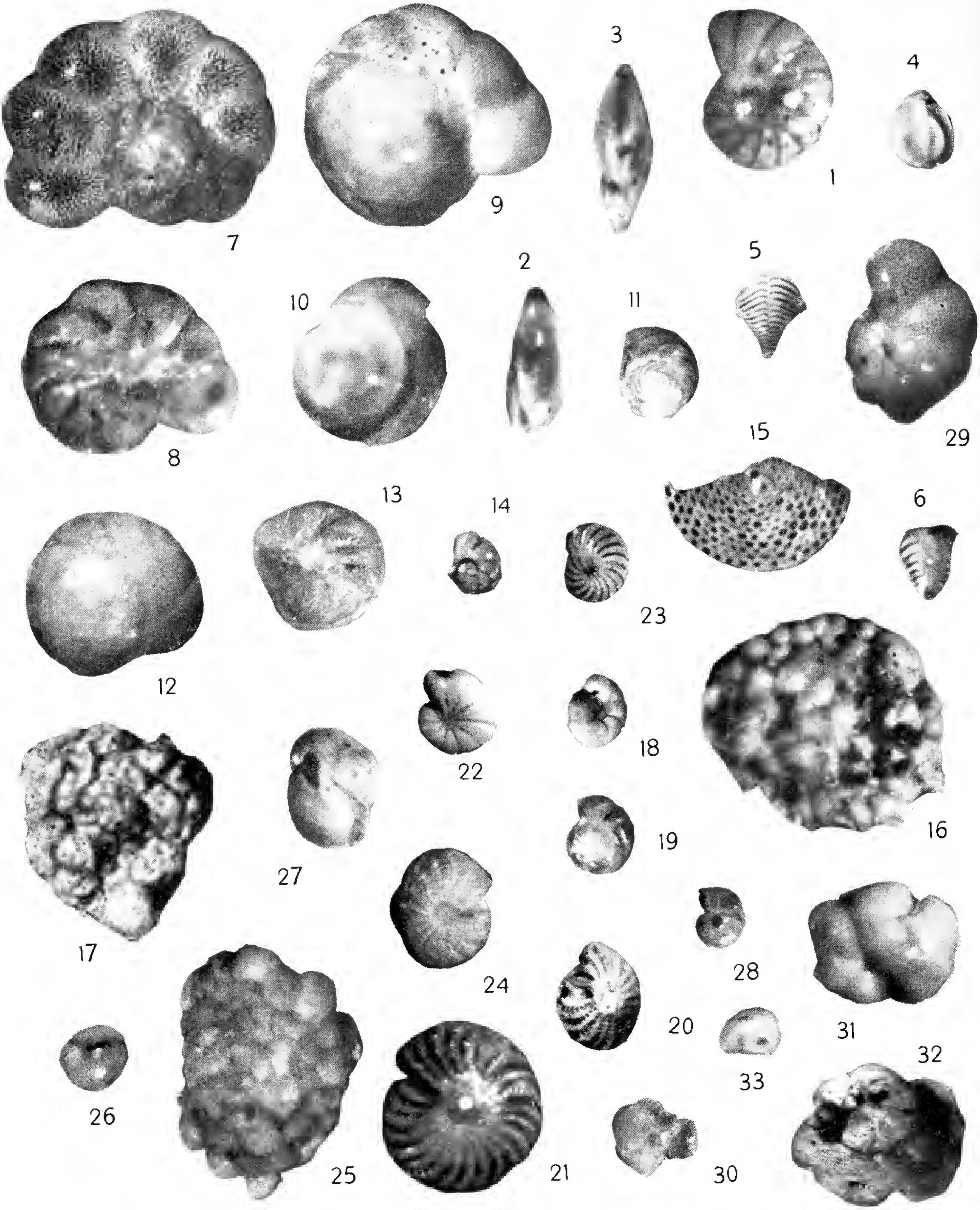
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PLATE III

convey must be integrated with that provided by the other groups now being studied (ostracods, echinoids, molluscs and weeds.)

The complexity of the other factors which control environment must also be emphasised. Of these, depth of water has been indicated by the depth contours on the sample location map; others which are important include the hydrologic regime (pH, Eh, chlorinity, temperature, phosphate and nitrate content), the lithotope, and climate, as well as abundance and type of competing plant and animal life.

To illustrate this complexity consider the hydrologic regime. Each of the components studied has a seasonal fluctuation, quite marked in some instances (temperature and chlorinity), but small in others (phosphate and nitrate content). The regime is the totality of these fluctuating components (and others which the author has been unable to study but which are generally considered of less significance), and the effect of any one of them on the environment can be considered only with reference to the hydrologic regime as a whole.

Similarly, the lithotope can be size-sorted and also sub-divided into its quartz-felspar, carbonate, organic matter, heavy mineral and clay fractions, which can then be analysed separately. As the size and proportions of these fractions vary so the lithotope alters, and again, the effect of any one fraction on the environment must be considered in relation to the lithotope as a whole at the location being studied.

The variables which determine climate are too well known to require elaboration here, and the same principle applies: that it is the interaction of these variables which determines climate, and therefore, that the effect of one of them on the environment must be determined with respect to its part in the climate as a whole.

Not only are the factors considered above complex within themselves, but they are complexly interwoven into the fabric which defines the environment. The environment is their ultimate expression.

A study of the environment, however, is not the purpose of this paper which is concerned with the identification of the species encountered in the samples examined and with their corrected nomenclature, and which is primarily a record of species occurrence; but the author intends to submit a separate paper in which the environments in Oyster Harbour will be analysed, and the complexities present, if not unravelled, at least clearly stated, and in which the foraminifera will have their place, among the other components of the biotope, as indices of environmental change.

Acknowledgments

Mr. C. W. Hassell assisted the author in collecting samples from Oyster Harbour during March, 1960.

Mr. R. A. McTavish, a research student of the Geology Department, University of Western Australia, checked the author's identifications, in some cases emending them, and suggested useful literature.

Dr. P. J. Coleman, of the Geology Department, University of Western Australia, suggested useful alterations to the form of the manuscript.

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PLATE III

1: *Peneroplis pertusus* (Forskål) x 30; 2: *Guttulina* cf. *lactea* (Walker and Jacob) x 30; 3: *G. yabei* Cushman and Ozawa x 30; 4: *Sigmoidella elegantissima* (Parker and Jones) x 30; 5: *Bolivinella folium* (Parker and Jones) x 30; 6: *Reussella ensiformis* (Chapman) x 30; 7: *Discorbis dimidiatus* (Jones and Parker) x 30. Dorsal view; 8: *D. dimidiatus* x 30. Another specimen; ventral view; 9: *D. dimidiatus* (Jones and Parker) var *acervulinoides* Parr x 30; 10: *D. mira* Cushman x 30; 11: *D. opercularis*(d'Orbigny) x 30; 12: *Eponides repandus* (Fichtel and Moll) x 30. Dorsal view; 13; *E. repandus* x 30. Another specimen; ventral view; 14: *Discorbinella biconcava* (Jones and Parker) x 30; 15: *Marginopora vertebralis* Quoy and Gaimard x 30. Broken specimen; 16: *Planorbulina acervalis* Brady x 30; 17: *Planorbulinella larvata* (Parker and Jones) x 30; 18: *Streblus beccarii* (Linné) x 30. Ventral view; 19: *S. beccarii* x 30. Another specimen; dorsal view; 20: *Elphidium advenum* (Cushman) x 30; 21: *E. crispum* (Linné) x 30; 22: *E. incertum* (Williamson) x 30; 23: *E. laminatum* (Terquem) x 30; 24: *E. macellum* (Fichtel and Moll) x 30; 25: *Planorbulina rubra* d'Orbigny x 30; 26: *Tretomphalus bulloides* (d'Orbigny) x 30; 27: *Carpenteria* sp. x 30; 28: *Nonion depressulum* (Walker and Jacob) x 30; 29: *Cibicides lobatulus* (Walker and Jacob) x 30. Dorsal view; 30: *C. pseudoungerianus* (Cushman) x 30. Ventral view; 31: *C. tenuimargo* (Brady) x 30. Dorsal view; 32: *C. tenuimargo* x 30. Ventral view; 33: *C. refulgens* (Montfort) x 30. Dorsal view.

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FORAMINIFERA — OYSTER HARBOUR

Species occurrence recorded as percentages of total foraminifera populations

No.	FAMILIES, GENERA, SPECIES, VARIETIES
	[illegible]DAE
1	[illegible]
	[illegible]DAE
2	[illegible]
3	[illegible]
4	[illegible] sp.
	[illegible]DAE
5	[illegible]
	[illegible]DAE
6	[illegible] polymorphinoides
	[illegible]DAE
7	Ammobaculites agglutinans
8	Haplophragmoides sp. aff. [illegible]
	TEXTULARIIDAE
9	Textularia [illegible]
10	[illegible]
	TROCHAMMINIDAE
11	Trochammina inflata
	ATAXOPHRAGMIIDAE
12	Gaudryina (Pseudogaudryina) hastata
13	Gaudryina triangularis
14	G. triangularis var. angulata
15	Clavulina difformis
16	C. pacifica
17	C. serventyi
18	Cribrobulimina polystoma
	NUBECULARIIDAE
19	Nubecularia lucifuga
20	[illegible] bradyi
21	[illegible] sp.
22	Spiroloculina [illegible] concentricum
23	Vertebralina striata
24	[illegible] sp.
25	Spiroloculina angulata
26	S. [illegible]
27	S. [illegible]
28	S. [illegible]
29	S. [illegible]
30	Planispirinoides bucculentus
	MILIOLIDAE
31	Pyrgo [illegible]
32	[illegible] cf. [illegible]
33	[illegible]
34	[illegible]
35	[illegible]
36	[illegible]
37	[illegible]
38	[illegible] sp. [illegible]
39	[illegible] circularis
40	[illegible] labiosa
41	[illegible]
42	[illegible]
43	[illegible] australis
44	Quinqueloculina bicornis
45	Q. bosciana
46	Q. bradyana
47	Q. costata
48	Q. dentata
49	Q. granulocostata
50	Q. cf. inaequalis
51	Q. lamarckiana
52	Q. poeyana
53	Q. polygona
54	Q. seminula
55	Q. seminula var. longa
56	Q. stelligera
57	Q. striata
58	Q. subarenaria
59	Q. suborbicularis
60	Q. subpolygona
61	Q. sulcata
62	Q. sp. 1
63	Q. sp. 2
64	Schlumbergerina alveoliniformis
65	Triloculinoides curta
66	Ptychomiliola separans
67	Pseudomassilina australis
68	Spirosigmoilina [illegible]
69	Massilina annectens
70	M. cf. planispiroides
71	M. secans
72	M. secans var. tenuistriata
	[illegible]DAE
73	Peneroplis [illegible]
74	P. [illegible]
75	P. sp.
76	[illegible]
77	[illegible]
78	[illegible] vertebralis

14.—Some Aspects of the Life Cycle of the Plant Pathogen Sclerotinia sclerotiorum in Western Australia

By Ruth M. Henderson*

Manuscript received—20th March, 1962

Observations on the life cycle of *Sclerotinia sclerotiorum* were made in the Perth area in Western Australia during 1957 and 1958. The stages of the cycle of sexual reproduction observed agree with those reported from other parts of the world.

Ascospores are regarded as the only significant source of host plant infection.

Introduction

During investigations on diseases caused by the fungus *Sclerotinia sclerotiorum* (Lib.) D. By., 1886 in Western Australia during 1957 and 1958, particular emphasis was placed on establishing the life cycle of the causal organism as this would facilitate researches on methods of control. Although the cycle of sexual reproduction has not been observed previously in Western Australia, it is known in other parts of the world and the ascospores liberated from the apothecia known to be capable of host plant infection (Lauritzen 1932, Keay 1939, Purdy and Bardin 1953, Purdy 1958). However, Hungerford and Pitts (1953) and Purdy (1958) showed in the laboratory that sclerotia in soil may germinate to produce hyphae which can infect host plants at ground level. On the other hand, Keay (1939), Loveless (1951) and Henderson (1958) have been unable to produce infection consistently by this means.

This paper presents observations on the life cycle of *S. sclerotiorum* made in market gardens in the Perth Metropolitan area where the disease has become serious due to susceptible crops such as beans and cauliflowers having been grown intensively over a number of years.

The Life Cycle

The morphological stages of the life cycle which have been observed in the Metropolitan area are presented in Figure 1.

Depending on the form of post harvest cultivation, diseased plant residue containing sclerotia is either buried to varying depths in the soil or remains in the surface soil only. Sclerotia in the surface soil are a potential source of inoculum for the following crop. In an attempt to assess the sclerotial population in the surface soil, samples of soil were taken from several market gardens. In one garden, rotary hoe cultivation only had been carried out on one half of an area which had previously supported a diseased crop, while the other half had been deep ploughed. As many as twenty sclerotia were removed from soil samples (approximately 1 ft. square and 2 in. deep) which were taken from areas which had been rotary hoed, while a maximum of two only was obtained from samples from areas which had been deep ploughed (Table I). It is clear that with continued shallow cultivation there would be a build-up of sclerotia in the surface layers of the soil. The effectiveness of deep ploughing in reducing sclerotial numbers in the surface soil might become less significant with time due to an overall build-up of sclerotia unless the majority of sclerotia had only limited viability. Mr. S. C. Chambers of the Department of Agriculture in Perth is working on this aspect.

TABLE I

*The Concentration of Sclerotia in the Surface Two Inches of Soil on the Property of Mr. Schultz, Balcatta**

Post Harvest Cultivation	Sample	Number of Sclerotia Per Sample (approx. 1 ft. sq. and 2 in. deep)
Rotary hoeing only	1	12
	2	10
	3	20
Deep ploughing	1	2
	2	0
	3	2

* Sclerotia were removed from soil samples by the method used by Campbell (1946).

Viable sclerotia in the surface soil may germinate to form apothecia a few weeks after the onset of moist conditions. In the winter months the moisture is supplied by the natural rains and in the autumn, summer and spring by overhead sprinkler systems. Apothecia have been found in diseased crops throughout the whole year, though they are definitely more numerous during the winter months. From the time the crop is planted until post harvest cultivation there is continued and increasing production of apothecia in areas where the disease is prevalent. Field tests (Henderson 1958) have shown that sclerotia formed in a diseased crop in June can produce apothecia in a following crop in July, August, September and October. However, although the first apothecium was produced within five weeks, only approximately 10 per cent. had germinated by the end of October. It appears that under natural conditions, sclerotia germinate irregularly, some taking

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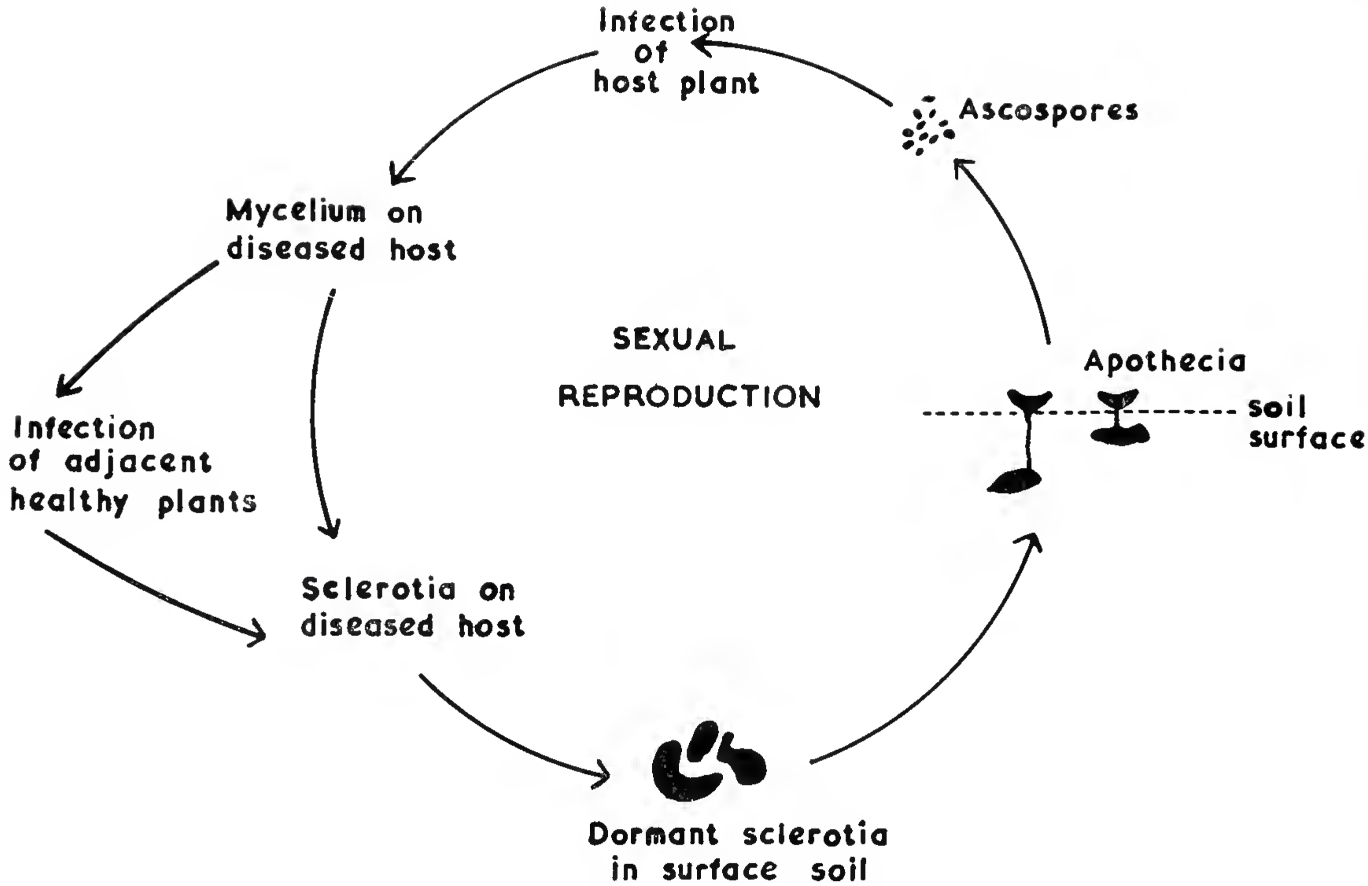

Fig. 1.—Diagrammatic representation of phases of the life cycle of *Sclerotinia sclerotiorum* observed in Western Australia.

much longer than others to produce apothecia. Tests were carried out by the author which showed that some sclerotia are capable of producing as many as three crops of apothecia over a period of four months (Henderson 1958).

In areas where the disease is prevalent a maximum average of nine apothecia-forming sclerotia has been found per square yard, each sclerotium producing one to several apothecia (Table II). As each apothecium may produce 30,000,000 ascospores (Ingold 1953) the number of ascospores released into the atmosphere may be very high. The ascospores are released from the apothecium over a number of days. Marked apothecia in the field have been observed to "puff" intermittently for a period of five to ten days.

Nowhere over a period of twelve months has a diseased crop been inspected without apothecia being found within the confines of the crop, or rarely, only in areas immediately adjacent to it. If basal infections were found, then apothecia were always observed in the immediate vicinity of the diseased plants. On the few occasions when only aerial infections were found, apothecia were not observed within the crop but were always easily found within neighbouring crops. It appears that after ascospores are liberated from the apothecia, they are carried by the wind onto adjacent host plants resulting in basal and aerial infections or rarely they may be carried further afield to neighbouring susceptible crops causing aerial infections only. Infection of host plant material with ascospores has been frequently reproduced in the laboratory.

TABLE II

Some Examples of the Density of Apothecia-forming Sclerotia in Market Gardens in the Metropolitan Area from April, 1957, to January, 1958.

Month	Property	Crop	Number of Apothecia-Forming Sclerotia Per Sq. Yd. (Av. of 10 Sq. Yd.)
April	Mr. Arbuckle, Balcatta	Cauliflower seed-bed	2
,,	,, ,, ,,	Cabbage seedbed	1
,,	,, ,, ,,	Mature cauliflower	6
May	Mr. Sawle, S. Coogee	Mature bean	1·5
,,	Mr. Goodchild, Spearwood	,, ,,	1
June	Mr. Arbuckle, Balcatta	Mature cauliflower	6
,,	Mr. Goodchild, Spearwood	Young bean	3
,,	Mr. Donnetti, Balcatta	Mature bean	2
,,	Mr. Sawle, S. Coogee	Mature cauliflower	9
July	,, ,, ,,	,, ,,	2
Aug.	,, ,, ,,	,, ,,	1
Sept.	Mr. Di Piazzi, Osborne Park	Mature celery	A few only
Nov.	Mr. Arbuckle, Balcatta	Mature cauliflower	A few only
Jan. 1958	Mr. Donnetti, Balcatta	Mature lettuce	7 (Apothecia under plants only)

In Western Australia during 1957 and 1958 *Sclerotinia* disease was observed on cauliflowers, cabbages, brussels sprouts, beans, celery, lettuce, tomato and on the herb *Portulaca oleracea* which

is often found as a weed in the preceding crops. Records show that in Western Australia *S. sclerotiorum* may also infect potatoes, lucerne, W.A. blue lupin, N.Z. lupin, citrus, apricot, passion vine and Calendulas (unpublished data in W. Aust. Plant Disease Records, Agric. Dep. W. Aust.; Annu. Rep. Plt. Path., Agric. Dep. W. Aust.; File 367/47, Agric. Dep. W. Aust.)

Masses of white hyphae are formed on the host plant several days after infection. This mycelium subsequently produces the black sclerotial bodies which later fall to the ground in the diseased crop residue.

No asexual spores have been observed on mycelium on diseased plants which might have caused further spread of the disease. However, mycelium may grow from a diseased plant directly onto an adjacent healthy plant.

Conclusions and Discussion

The stages of the cycle of sexual reproduction for *Sclerotinia sclerotiorum* observed in the Perth Metropolitan area, Western Australia agree with those found in other parts of the world.

It has been observed that there is a definite sclerotial population in the soil in areas where the disease is prevalent. These sclerotia are a potential source of inoculum whenever environmental conditions are suitable.

The presence of abundant apothecia in areas where the disease is prevalent implies that host plant infection is primarily due to ascospores. Furthermore, as no diseased crop with basal infections has been observed without apothecia being found on the soil in the immediate vicinity there has been no reason to suspect that any infections observed could have resulted from hyphae produced directly by sclerotia. The author (1958) has failed to produce this form of host plant infection in the laboratory except for one instance. This was in agreement with findings of Keay (1939) and Loveless (1951) but contradictory to the work of Hungerford and Pitts (1953) and Purdy (1958). The author considers that although hyphal infection by sclerotia may take place occasionally, it is not of practical signficance.

No asexual spores on host plant mycelium which might cause secondary infections have been observed.

Acknowledgments

The author would like to thank Professor B. J. Grieve, Botany Department, University of Western Australia and Mr. W. P. Cass-Smith, Department of Agriculture, Perth, for their interest and assistance.

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Journal

of the

Royal Society of Western Australia, Inc.

Volume 45 1962

Part 4

Contents

Editor: J. E. Glover

Assistant Editors: G. F. Mees, R. D. Royce

Annual Subscription: Forty Shillings

The Royal Society of Western Australia, Inc., Western Australian Museum, Perth

60377/7/62—535 ALEX. B. DAVIES, Government Printer, Western Australia